ASTRONOMY

February 1994 U.S. $2.95
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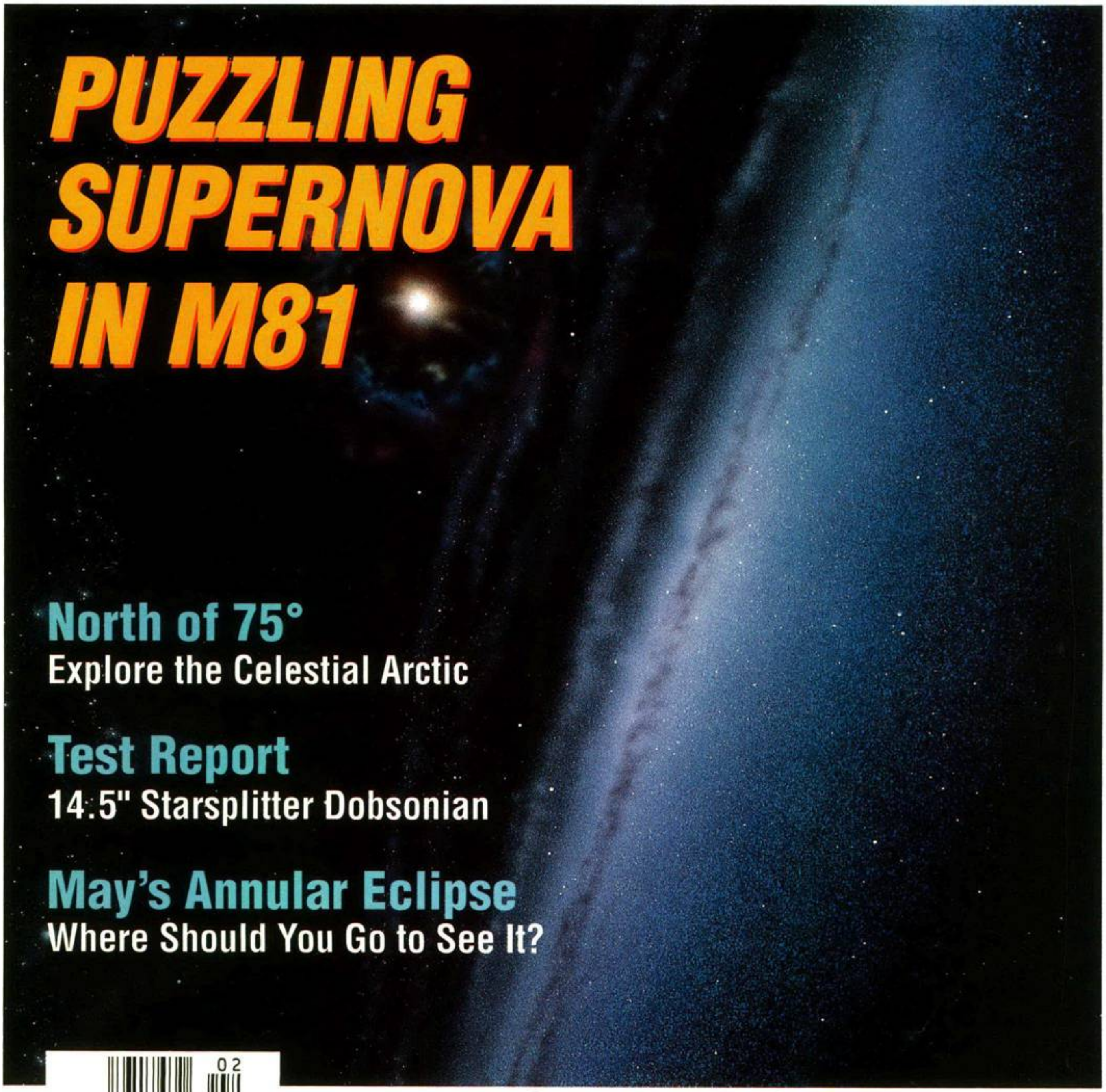
Clementine:
New U. S. Mission to the Moon



PUZZLING SUPERNOVA IN M81

North of 75°
Explore the Celestial Arctic

Test Report
14.5" Starsplitter Dobsonian

May's Annular Eclipse
Where Should You Go to See It?

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- Capturing the Sky's Color & Light
- Dwarf Galaxies: Keys to the Local Group

MEADE
MEADE LX200 EMC
12" LX200
8" LX200
10" LX200 (shown with optional Superwedge)

Supplied complete per catalog specifications**:

8" LX200 Schmidt-Cassegrain	**$2295.**
Equatorial Wedge 8"	**110.**
10" LX200 Schmidt-Cassegrain	**2895.**
12" LX200 Schmidt-Cassegrain	**3995.**
Superwedge 10"/12"	**395.**

Packing & shipping in 48 states: 8"—$105; 10"—$145; 12"—$215.

- **All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

- For dealer or catalog information see the **Meade Starfinder Reflecting Telescope** ad in this issue.

LX200 SCHMIDT-CASSEGRAINS:
New Technical Advances for 1994.

Six new technical advances that extend Meade's position at the leading edge of telescope technology:

1. 18-volt Dual-Axis Drive Systems

—All Meade 8", 10", and 12" LX200's now include **18-volt DC power systems,** superseding the previous 12-volt systems, with the result that **LX200 motor torques are increased by about 60%** over previous models. Combined with new, more efficient DC motor electronics, these powerful, high-torque drives, on both telescope axes, yield a level of drive smoothness heretofore unavailable on any commercial telescope.

2. Ultra-reliable Electronic Systems

—Recent electronic refinements in the main circuit boards, the hand controller, and in the control panel electronics have made Meade's new advanced LX200's more reliable than ever before. State-of-the-art improvements in microcircuitry, combined with *thousands* of hours of laboratory and field testing, result in **the most trouble-free serious telescopes ever manufactured.**

3. New *Version 3.20* Software

—As recently announced, Meade *Version 3.20* software is the very latest in telescope operating systems and permits **quick (less than 10 seconds!) 2-star alignment** of the LX200 in the altazimuth mode, without requiring your latitude or longitude, without even leveling the tripod. Just use 2 easy-to-find reference stars and the telescope tracks and actuates GO TO with extreme precision.

*For safety reasons AC-powered personal computers should be used indoors only.

Meade 8", 10", and 12" LX200 Schmidt-Cassegrains include an RS-232 serial port (PC connector) on the power panel.

MEADE LX200
COMPUTER DRIVE SYSTEM
LX QUARTZ – DC SERVO MOTOR
SMART DRIVE
Current (mA x 100)
On
Off
N
S
Encoders
RS232
Focuser
Reticle
Keypad
Power 18vDC
CCD
DEC Motor

4. Software Library Options

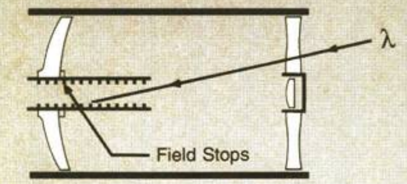
Included with every LX200 is a basic 747-object database of the finest deep-space objects, reference stars, and the 8 major planets. *Version 3.20* LX200 software allows for two new optional object libraries:

—**Library Option 1:** An object database of **10,600** celestial objects taken from the Messier, NGC, and IC catalogs. Available at $99.**

—**Library Option 2:** An object database of **64,350** celestial objects, including the 10,600 objects of Library Option 1, above. Available at $149.**

5. PC-Interface Capability

Meade AstroSearch/200™ sky software permits the interface of a personal computer (PC) to your LX200. Just load Meade AstroSearch/200 software into your PC, connect the PC* to the LX200's PC port (located on the telescope's power panel) and you're ready to **point-and-click on any of 45,000 planetary, deep-space, or stellar objects** now visible on the PC display. As you point-and-click, the LX200 slews at high-speed (up to 8°/second) simultaneously on both axes, precisely centering the object in the field of view. **The Meade AstroSearch/200 celestial software package, supplied on 3.5" discs for Windows™ 3.1 or higher, is available from Meade dealers at $99.95**.**



Field-stops *(arrow),* now included on Meade 8", 10" and 12" Schmidt-Cassegrains, significantly increase image contrast by effectively blocking off-axis stray light rays, λ.

6. Contrast-Enhancing Field Stops

—All Meade 8", 10", and 12" Schmidt-Cassegrains now include a series of computer-optimized internal field stops, for greater rejection of unwanted stray light than ever before possible. These field stops, machined into the inside-diameter surface of the primary-mirror baffle tube *(see diagram),* **significantly increase lunar, planetary, and deep-space image contrast,** compared to SCT's not so equipped.

Plus all of the features that have already made Meade® LX200's the largest-selling serious telescopes in the world:

- **Legendary Meade Super Multi-Coated (EMC) Schmidt-Cassegrain Optics** —The finest SC optics available, optics that yield razor-sharp stellar images and high-resolution observing of the Moon, planets, and deep-space.
- **Heavy-Duty Fork Mounts**—The largest, most rigid in the industry, complemented by large 4"-diameter polar ball bearings and by DC servo-motor-driven worm gears on both telescope axes.
- **Four-speed Drives on both Telescope Axes**—Including photo-guiding (at **2x** sidereal rate); image centering and microslewing in the main telescope (at **32x** sidereal rate); image centering in the viewfinder (at **2**°/sec.); or fast-slew of the main telescope across the skies (at up to **8**°/sec.).
- **Digital Readouts**—On both axes, read from the keypad hand controller.
- **GO TO Capability**—Enter the RA and Dec of an object into the keypad hand controller, press GO TO, and the telescope slews to the object at up to 8°/sec., centering it in the field.
- **747-Object Built-in Library**—Enter any of the 110 Messier objects, 278 of the finest NGC objects, 351 stars (doubles, variables, reference stars), or one of the 8 planets (from Mercury to Pluto), press GO TO, and the telescope slews at up to 8°/sec., centering the object in the field.
- **Permanently Programmable Smart Drive™** —Capable of reducing periodic drive errors to 5 arc. secs. or less, an observatory standard.

Specifications: 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 SC optical tube assembly with super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; keypad handheld controller with digital readout display, PPEC Smart Drive, four-speed drive control on both axes, GO TO controller, and 747-object software library; 25 ft. power cord and adapter for telescope operation from 115v.AC (DC capability for operation from auto cigarette lighter plug available optionally); 8 x 50mm viewfinder with crosshairs; 1.25" diagonal prism (8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (8", 10") or giant field tripod (12"); foam-fitted carrying case; complete operating instructions.

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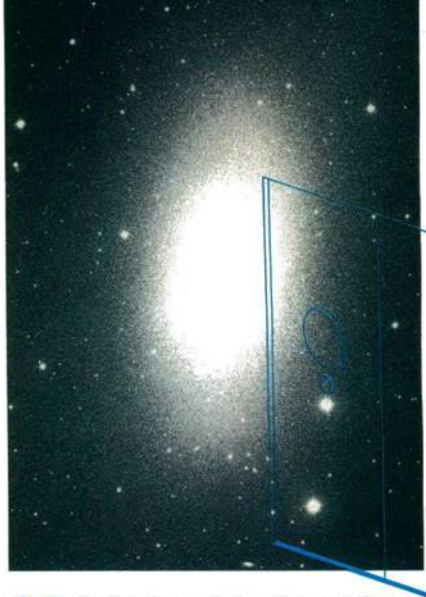
ASTRONOMY

Paul Rodmell



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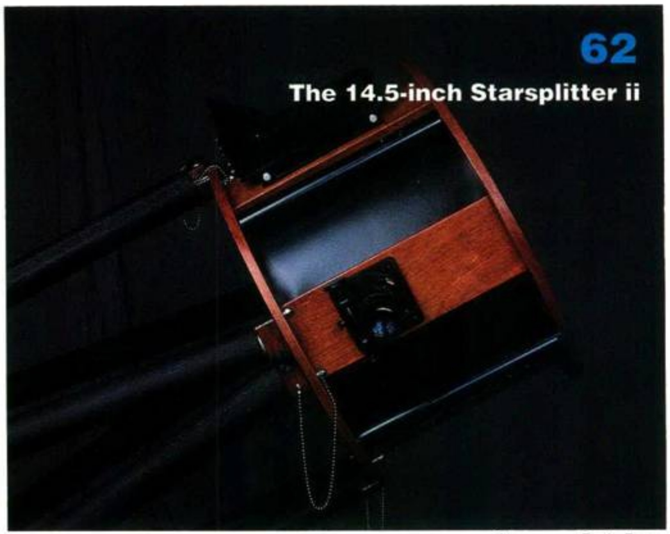

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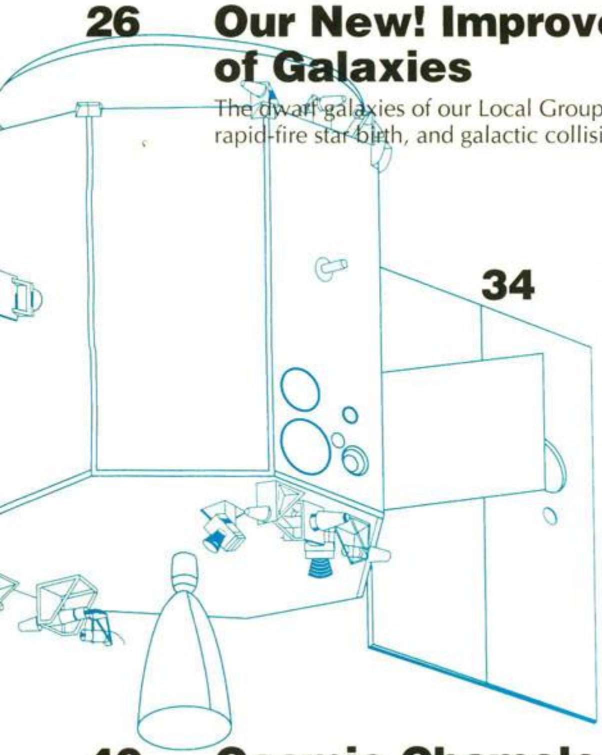

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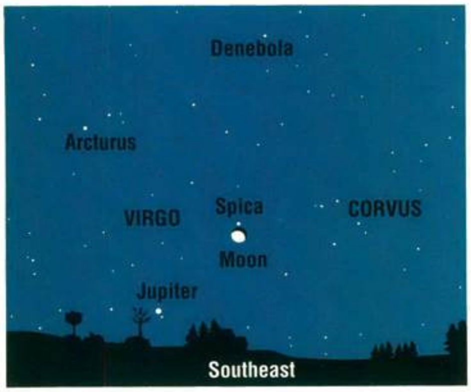

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COVER

A STAR EXPLODES in the outskirts of M81, a nearby spiral galaxy in Ursa Major. To see how this March 1993 supernova is changing our view of these stellar cataclysms, turn to page 40. Illustration by Michael Carroll.

BEHIND THE SCENES

Refreshing Astronomy

Hours spent at the telescope under a black, starlit sky. Finding a nebula in some region I've never before visited. Spotting a "new" feature on the Moon when the setting Sun lights it in a novel way.

These are a few of the ways in which astronomy refreshes me and perhaps you, too. After work, on weekends or vacation — whenever the world presses in on life too tightly — it's time to take out the telescope and get straight with the sky again.

But while astronomy has the ability to refresh us as nothing else can, did you ever wonder if astronomy itself needs refreshing? I suspect it does, and I think what refreshes astronomy are new discoveries, new techniques, and new puzzles. As it happens, three features this month each revolve around one of these elements.

A new discovery that gave galactic astronomy a jolt was the finding that some dwarf ellipticals in the Local Group had recent bursts of star formation. That may not sound exciting, but it wasn't supposed to happen. A dwarf elliptical galaxy should form, make stars once, and then grow old quietly — not behave like a staid, bachelor uncle kicking over the traces in middle age. The discovery is telling astronomers they'd better look again at all the galaxy groups we can see.

A new technique involves the Clementine spacecraft mission to the Moon and Geographos, an asteroid. Despite a name that harkens to the Gold Rush, Clementine will carry instruments so advanced they ought to be Top Secret. This isn't a joke: Clementine is the first collaboration between the Department of Defense and NASA on a mission to the planets. Has DoD suddenly gone "Green?" Not quite. But if this marriage of highly dissimilar cultures comes off, I'll bet we see more of them. Both parties stand to gain too much. The brass can test their hardware while putting it to peaceful uses, and the folks who inhabit planetary science get vital new data. It's tempting to call Clementine a marriage made in heaven, but — oh, never mind.

One new puzzle giving astronomy a boost recently involved something astronomers thought they had figured out: supernovae. Last spring's supernova in M81 was a fine sight; I hope you got a chance to see it. Because amateur astronomers tipped off the professionals to the supernova early in its outburst, the pros could track its changes in unprecedented detail. And that revealed that the supernova wasn't behaving as it "should." Nearly a year after the outburst, astronomers are still working out just what happened. But already it's clear that thanks to some sharp-eyed amateur astronomers, mankind's picture of the cosmos will become a little clearer.

For the most part, we amateur astronomers take from astronomy, drawing on it endlessly for recreation and renewal. It's nice now and then when some of us can give something back.

Sincerely,

Robert Burnham
Editor

LETTERS

Spectroscopic Survey Scope Update

Your article "Dawn of a New Era: Big Scopes" (August 1993) contained some outdated information relating to the Spectroscopic Survey Telescope, which will be completed in 1997. An improved design has reduced the mass of the telescope and the number of parts required to build it. The primary mirror will consist of 91 segments. The telescope will rotate through a full 360° of azimuth to conveniently access all parts of the sky. The tracking range permits us to track objects for time periods on the order of one hour. — *Thomas A. Sebring, project manager, Spectroscopic Survey Telescope, The University of Texas at Austin, Austin, Texas*

Jove's Hammer

I enjoyed your coverage of the upcoming July 1994 collision of Comet Shoemaker-Levy 9 and Jupiter, in July 1994 (January 1994). I hope that you will continue to cover this event prominently. Incidentally, has anyone considered the possibilities of a comet's colliding with Earth? — *Calvin J. Maestro, Jr., Dyer, Indiana*

— Look for monthly coverage of the impending impact on Jupiter. For information on comets and Earth, see "Death from the Sky" (December 1993).

Best Observatory on the Block

I found your November 1993 issue outstanding for its article on the lunar eclipse, the piece on constructing an observing chair, and the article on building a dew cap. I applaud the two project articles — can we see more of them?

Another suggestion: Can you hold a contest to feature the best and most affordable observatory design from the readers? Publishing a story about this would help many of us think through

(continued on page 12)

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MK65/sturdy Alt/Az. mount package (with slow-motion) - only **$1295**($20)

This is the opportunity of a lifetime! Own a high quality 6" f/10 Maksutov-Cassegrain telescope for a fraction of what you would expect to pay.

Aperture-for-aperture, the Maksutov is recognized to be superior to any other telescope design. **JMI** stands behind these little beauties from Russia. We star test each and guarantee them to equal or surpass a Questar 3.5 or Quantum 6 in resolution and contrast. We have also increased the back-focus so they will focus with all popular eyepieces.

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"I, as well as two other experienced observers, have been comparing the Intes **MK65** to the Quantum 6", and we all agree [the **MK65**] is equal in resolution and equal or better in contrast." - S. Dunne

"The Intes optics are superb! Several of my observing friends and I have been comparing the **MK65** side-by-side with the Questar, and the **MK65** is right there. When you consider the portability, optics and price, it's incredible." - D. Murray (45 years experience)

"I haven't seen a set of optics to match this in any telescope for quite a while...they are *bloody superb!* My Ronchi screen shows absolutely straight lines." - C. Garner, Australia

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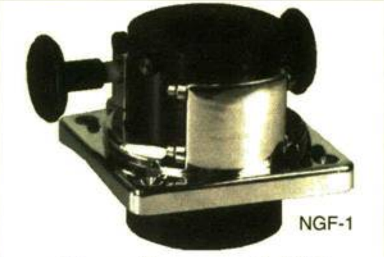
At last! Encoders for the popular Polaris mount. Use any of our four computer units with your Polaris-mounted telescope. Even use the new **MOTOTRAK IV** or **V** with our R.A. and Dec. motors.



Zero image shift!

"I was able to see for the first time the Crepe Ring...I feel this is due to the very fine focusing that can be done with the **NGF-S**." - Donald A. Regan

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manual, 6 SS bearings*	**$229**
with integrated **MOTOFOCUS**	**$299**

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*SS=Stainless Steel, CB=Composite/Brass, AA=Anodized AL.

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*The term "PEC" is licensed from Tangent Instruments.

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12.5" f/4.8
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8" f/6
$395.

Shown with optional #637 6 x 30mm or #545 8 x 50mm Viewfinders.

6" f/8
$295.

SPECIAL ACCESSORY OFFER!

Through March 31, 1994, at the time you order any Starfinder 6", 8", 10", 12.5", or 16" Dobsonian Telescope, you can buy **two additional Meade multi-coated Modified Achromatic MA9mm and 12mm eyepieces *and* the Meade #637 6 x 30mm coated achromatic viewfinder for a *total* of only $29.95! Purchased separately, the 2 additional eyepieces and viewfinder sell for $109.85!** *(Shown in photo: MA9mm, MA12mm, and standard-equipment MA 25mm eyepieces, with #637 6 x 30mm viewfinder.)*

Starfinder Dobsonian 16

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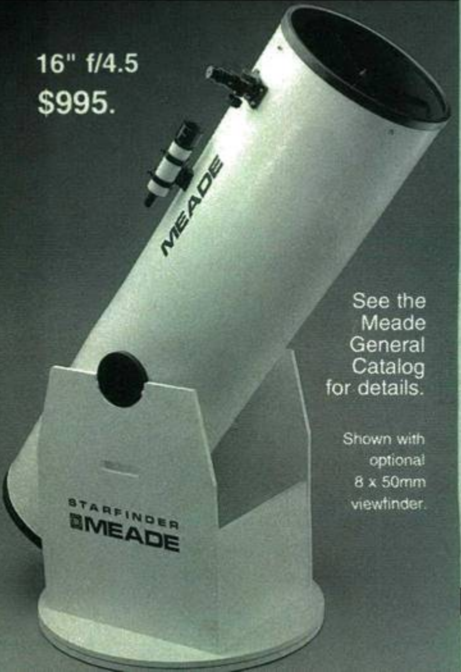
$995.



See the Meade General Catalog for details.

Shown with optional 8 x 50mm viewfinder.

Compare Meade Starfinders *feature-for-feature* with other similarly priced Dobsonians!

- **Primary and Secondary Mirrors of Low-Expansion Pyrex® glass!** Unlike the plate-glass optics of other Dobsonians that can become thermally unstable (especially in larger apertures), Meade Dobsonians include the *exact same* professional-quality Grade-A, fine-annealed Pyrex® optical systems used on Meade Starfinder Equatorial Reflectors. Optics that meet the theoretical limits of resolution for their apertures.
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- **To Order:** Contact one of the authorized mail-order dealers listed on the facing page.

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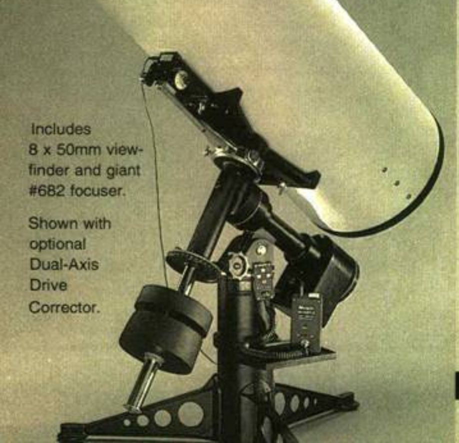
Starfinder Equatorial 16



16" f/4.5
$2195.

See the Meade General Catalog for details.

Includes 8 x 50mm viewfinder and giant #682 focuser.

Shown with optional Dual-Axis Drive Corrector.

Standard equipment on 6", 8", and 10" models includes:

- **Superb Optical System:** Includes hand-figured parabolic primary mirror that meets the theoretical limit of resolution for its aperture, with matching elliptical flat secondary mirror. Both mirrors multi-coated and made of low-expansion, Grade A, fine-annealed Pyrex® glass.
- **Precision Equatorial Mount:** Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs, for rock-solid support of the optical tube. The telescope moves effortlessly from object-to-object on precision bearing surfaces. Polar and declination shafts are 1" solid steel. Setting circles on both axes facilitate the location of faint objects directly from their catalogued coordinates.
- **Electric Motor Drive** (115v/60Hz) with 6 ft power cord: permits **fully automatic** tracking of celestial objects; plugs into any standard outlet.
- **Standard Accessories and Components:** Precision Rack-and Pinion Focuser (1.25") with full 2.6" travel; coated achromatic #637 6 x 30mm Viewfinder with crosshair eyepiece and 7° field; multi-coated MA25mm (1.25") eyepiece, threaded for filters; strong, durable, spiral-wound optical tube with attractive white finish.
- **Optional Accessories:** See the Meade accessories ad in this issue. Additional systems, including #55 Manual Declination Control, #43 Drive Corrector, and #47M Dual-Axis Drive Corrector, are described in the Meade General Catalog.

SPECIAL ACCESSORY OFFER! Through March 31, 1994, at the time you order any Starfinder 6", 8", 10", or 16" Equatorial Telescope, you can buy **two additional Meade multi-coated Modified Achromatic MA9mm and 12mm eyepieces for a *total* of only $19.95! Purchased separately, the two additional eyepieces sell for $59.90.** *(Shown in photo: MA9mm, MA12mm, and standard-equipment MA 25mm eyepieces.)*

- **Packing and UPS Shipping Charges:** to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90. 16"—$55 packing, shipped truck freight collect.
- All prices shown are suggested USA mail-order retail prices, not including any applicable sales taxes.
- The **1994 Meade General Catalog**—$3.00 postpaid—is available from any authorized Meade dealer or directly from Meade Instruments.
- For further information call Meade Instruments at 714-756-2291 or contact one of these authorized mail-order dealers:

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE COMPANY, Burbank, CA.
Orders: 800-843-4780; Info.: 818-505-8424.

CITY CAMERA, Dearborn, MI.
Orders: 800-359-5085; Info.: 313-846-3922

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Illinois & Info.: 312-332-2000.

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KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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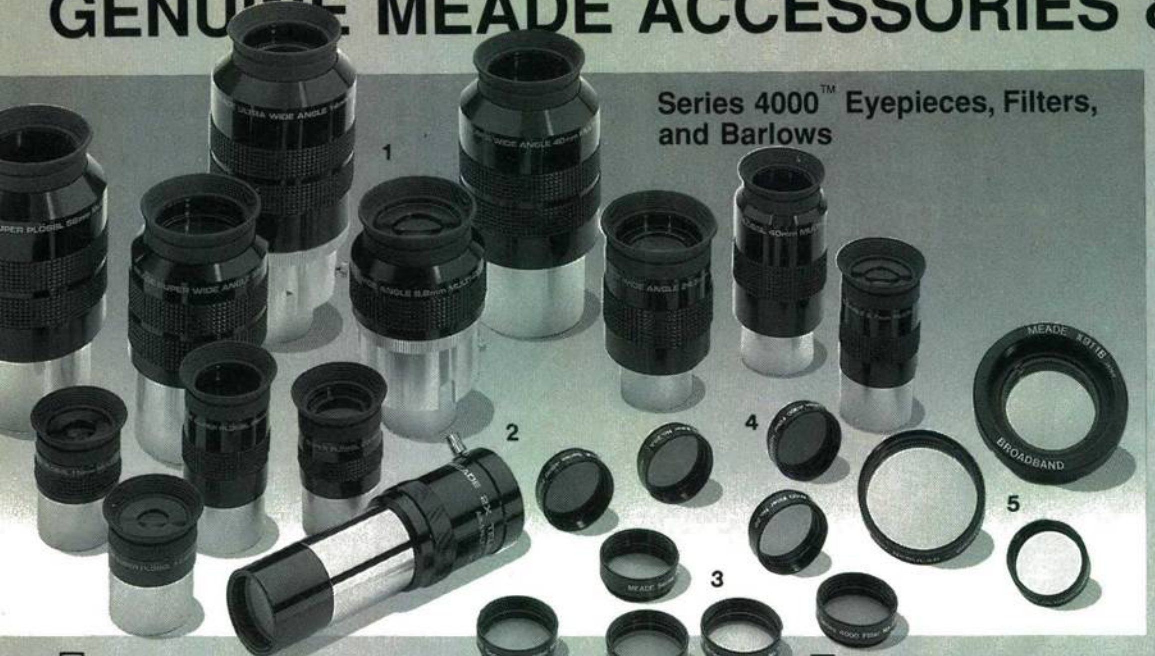


Series 4000™ Eyepieces, Filters, and Barlows

1 The World's finest telescope eyepieces now include rubber grips and soft rubber eyeguards for an even better observing experience! All eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Best of all, **Meade Series 4000's are guaranteed to deliver more field, more contrast, and more image sharpness than any other brand at any price, or your money back.*** For splitting the closest doubles, revealing tenuous, faint nebulosity in deep-space, or studying hairline lunar and planetary detail, Meade multi-coated Series 4000's are the oculars that serious observers insist upon. ***"Clearly the best."***

Super Plössls (5-elements; 1.25"; 52°):
6.4; 9.7; 12.4; 15; 20; 26mm ea **$87.95** (3.29)
32mm(52°); **40mm**(44°); each **109.95** (3.79)
56mm (52°, 2") **229.95** (4.78)

Super Wide Angles (6-elements; 1.25"; 67°):
13.8mm:159.95 (3.49) **18mm:169.95** (3.69)
24.5mm:199.95 (3.89) **32mm**(2")**:279.95** (4.78)
40mm(2"): **339.95** (4.78)

Ultra Wide Angles (8-elements, 1.25"; 84°):
4.7mm: 179.95 (3.29) **6.7mm: 219.95** (3.29)
8.8mm(1.25"/2"): **269.95** (4.78)
14mm(1.25"/2"): **329.95** (4.78)

*at participating dealers; see catalog for details.

2 **#140: Series 4000 2x Apochromatic Barlow Lens** (1.25")--The original Meade 3-element, air-spaced, multi-coated design. Absolutely unmatched in image resolution and color correction. 28mm dia. lens (26mm clear aperture). **$79.95** (3.29)

3 **Series 4000 Photo-Visual Color Filters** (1.25")—Made of purest crown optical glass, dyed in the mass. For increased contrast on the Moon and planets . Thread into virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow-Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue.

each **$12.95** (2.29)

Set #1—4 filters: #12 Yellow, #23A Lt.Red, #58 Green, #80A Blue **$49.95** (2.79)

Set #2—4 filters: #11 Yellow-Green, #25A Red, #47 Violet, #82A Lt. Blue **$49.95** (2.79)

Set #3—4 filters: #8 Lt. Yellow, #21 Orange, #38A Dark Blue, #56 Lt. Green **$49.95** (2.79)

Sets #1 & #2—8 filters **$89.95** (3.29)

Sets #1, #2, & #3—12 filters **$129.95** (3.48)

4 **Series 4000 Moon Filter** (1.25")—Excellent for 4" to 12" telescopes. Reduces Moon brightness by 87%. **$15.95** (2.49)

5 **Series 4000 Nebular Filters**—The very latest in multi-layer interference coating technology, Meade premium nebular filters are guaranteed to be the finest obtainable at any price. Use a Series 4000 Broadband filter to block most forms of light pollution, with minimal attenuation of desired wavelengths. Use a Narrowband filter in heavily light-polluted areas, or for extremely high contrast observing of faint nebulae.

BROADBAND FILTERS

#908B (1.25")—Threads into all Meade 1.25" eyepieces, and virtually all other brands. Full 26mm clear aperture. **$79.95** (2.49)

#910B—Threads into all Meade 2" eyepieces and most others; 44mm dia. **119.95** (2.79)

#911B--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **99.95** (3.29)

NARROWBAND FILTERS

#908N (1.25")—Threads into virtually all 1.25" eyepieces; 26mm clear aperture. **89.95** (2.49)

#910N—Threads into all Meade 2" eyepieces and most others; 44mm dia. **129.95** (2.79)

#911N--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **119.95** (3.29)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Internal batteries included. Multi-coated optics. Bullseye reticle. 1.25" **$129.95** (3.29)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$109.95** (3.29)

MA 12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Includes wireless red LED illuminator with internal batteries and variable brightness control. **$94.95** (3.29)

MA 12mm–Same as above, but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$74.95** (3.29)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter **$99.95** (3.29)

Camera Adapters (1.25" & .965")

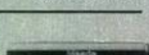
Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-Mount, available separately.

.965": $27.95 (2.79) **1.25": $29.95** (2.79)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera. **$39.95** (2.79)

Tele-Extenders

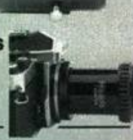


For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Use with T-Mount for your camera.

Basic Tele-Extender:*(above)* Fixed projection power; use with eyepiece for lunar and planetary photos. **$29.95** (2.79)

Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece. **$39.95** (2.79)

T-Adapters for SCT's

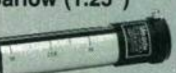


For Prime Focus photography with any Meade or Celestron SCT. Use with T-Mount for your 35mm camera. **$26.95** (2.79)

2X Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (3.29)

2x-3x Variable Barlow (1.25")



#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25" **$59.95** (3.29)

Orthoscopic Eyepieces (1.25")

Fine 4-element oculars that yield excellent image quality with any telescope. Computer-optimized design provides wide, flat fields, highly corrected for spherical and chromatic aberrations. Parfocal, multi-coated, 1.25" barrels. Threaded for filters. **Focal Lengths: OR 4, 6, 9, 12.5, 25mm.**

each **$49.95** (2.79)

Modified Achromatic Eyepieces

An improvement on the traditional Kellner design, the 3-element MA gives sharp, faithful, well-corrected images of the Moon, planets, and deep-space. Multi-coated, threaded for filters. 1.25" **Focal Lengths: MA 9, 12, 25, 40mm.**

each **$37.95** (2.79)

Rack-and-Pinion Focusers (1.25")

The finest focusers in the industry. Meade rack and pinion mechanisms have precise, ultra-smooth action along the entire travel distance. Housings are machined for tight fit of the moving sleeve. All focuser models may be used on tubes of from 4" to 20" diameter; all accept 1.25" eyepieces. Mounting hardware included.

#71—The finest economical focuser available. Travel distance: 2.2" A precision mechanism, beautifully finished. **$44.95** (2.79)

#67—Includes spring-loaded gearbox for variable tension adjustment. Travel distance: 2.2". **59.95** (2.79)

Rack-and-Pinion Focusers (2")

#680--The most popular 2" focuser ever manufactured. Thousands in use. Spring-loaded gearbox; 3" travel. Includes 1.25" and 2" eyepiece-holders. **99.95** (3.78)

#682—Low-profile 2" focuser; body height only 1.75". Spring-loaded gearbox. Travel: 2.5". Includes 1.25" adapter. **99.95** (3.78)

Viewfinders: 30mm, 50mm, 60mm

#637: 6 x 30mm–Fine, 7° wide-field finder; coated, achromatic lens; crosshair eyepiece, 2-ring bracket with alignment screws. Attaches to tube diameters 6" to 12" **$49.95** (3.29)

#545: 8 x 50mm–*(lower photo)* Wide 5° field; coated achromatic objective; crosshair eyepiece. White tube. Ideal for telescopes of any aperture. See bracket below. **69.95** (4.28)

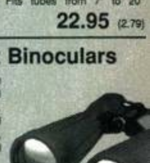
#544: 8 x 50mm–– Same as #545, but in Meade blue. **69.95** (4.28)

#957: 9 x 60mm–– *(top photo)* Collects 44% more light than 50mm; superior for faint objects; bracket below. **99.95** (4.68)

Bracket for 8 x 50mm: Fits Meade and Celestron SCT's, and other tubes from 7" to 20" diameter. **17.95** (2.79)

Bracket for 9 x 60mm: Fits tubes from 7" to 20" diameter. Removable dovetail included. **22.95** (2.79)

Multi-Coated Giant Binoculars



Superb, fully multi-coated 11 x 80mm and 20 x 80mm Giant Binoculars, ideal for wide-field deep-space observing. **Rubber-coated bodies for rugged field use!** BAK-4 prisms yield bright, sharp, high-contrast images. Hard carry case, tripod adapter included.

11x80: $399.95 (7.27)
20x80: $419.95 (7.27)

45° Erect-Image Diagonal Prisms

Originally developed by Meade Instruments, these convenient diagonals erect the astronomical image, for terrestrial use of astronomical telescopes. Fully coated.

#927: for .965" focusers.
#928: for 1.25" focusers.
#931 Hybrid: accepts 1.25" eyepieces, fits .965" focusers.

Specify model desired. each: **$49.95** (2.79)

HOW TO ORDER

- Prices shown are suggested USA mail-order retail prices and do not include any applicable sales taxes.
- Suggested shipping and handling charges to the 48 states by UPS or US Mail shown in ( ) next to each price.
- Meade accessories may be ordered from any Meade Advanced Products dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA
Orders: 800-843-4780; Info: 818-505-8424.

CITY CAMERA, Dearborn, MI.
Orders: 800-359-5085; Info.: 313-846-3922

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info: 510-447-9570.

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KHAN SCOPE CENTRE , Toronto, Ontario.
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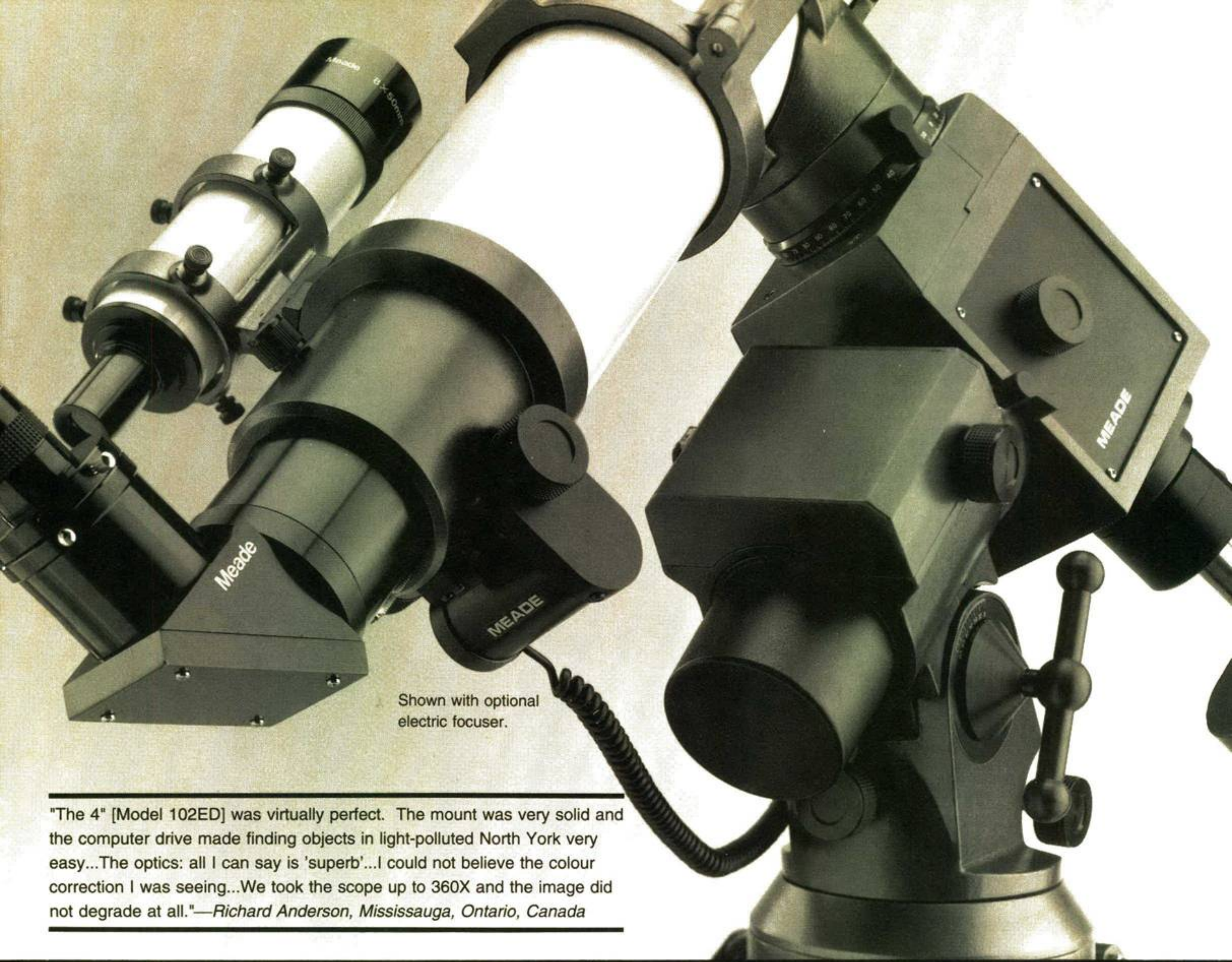

Shown with optional electric focuser.

"The 4" [Model 102ED] was virtually perfect. The mount was very solid and the computer drive made finding objects in light-polluted North York very easy...The optics: all I can say is 'superb'...I could not believe the colour correction I was seeing...We took the scope up to 360X and the image did not degrade at all."—*Richard Anderson, Mississauga, Ontario, Canada*

MEADE® ED APOCHROMATIC REFRACTORS

The finest in super-high resolution telescopes—now even more advanced for 1994!

Meade USA-made ED Apochromats combine uncompromised image quality with a level of equatorial mounting precision, stability, and sophistication available from no other commercial manufacturer.

Optical Designs: The ED-lens designs of Meade 4", 5", 6", and 7" apochromats yield image quality generally reserved only for the most advanced professional instruments. As one Meade 6" ED/APO user remarked, "Image quality even to the edge of the field is outstanding, while the color correction and contrast are simply better than any telescope I've ever used." Another 4" ED/APO owner stated, "The mount is extremely rigid...the computer drive performs flawlessly...the optics are superb." (See the Meade ad in the 12/92 issue of this magazine for references.)

New LXD 650 and LXD 750 Equatorial Mounts: Identical in external appearance to their predecessor LXD 600 and 700 mounts, new Meade LXD 650 and 750 mounts include important internal technical advancements for 1994:

- **Redesigned worm gear systems**—New worm gear engagement assemblies **virtually eliminate gear backlash**, resulting in the most rigid, flexure-free mountings available.
- **Optional #1697 Computer Drive System now with 18-volts Power Input**—RA and Dec motor torques of the #1697 CDS are now **increased by 60%** from the values of the previous 12-volt systems. These powerful, high-torque systems yield extremely smooth motion of the telescope even in the 8°/sec. fast-slew mode. Each CDS includes an 18v.DC power supply, operable from standard 115v. outlets.

If you're looking for the most advanced, super-high-resolution refractors available, and yet priced within the budget of most serious amateurs, call or visit your authorized Meade dealer today.

Complete ED Apochromatic Refractors*

Specifications—Each complete telescope includes optical tube assembly with #684 giant 2.7" focuser, 8 x 50mm viewfinder, #930 2" diagonal mirror with 1.25" adapter, and Super Plössl 26mm eyepiece; 4" and 5" models include the LXD 650 equatorial mount and standard field tripod; 6" and 7" models include the LXD 750 equatorial mount and giant field tripod; each mount is provided with manual slow-motion controls, analog setting circles, and locks on both axes.

Model 102ED:	4" f/9 ED/APO complete	**$2195.**
Model 127ED:	5" f/9 ED/APO complete	**2795.**
Model 152ED:	6" f/9 ED/APO complete	**4495.**
Model 178ED:	7" f/9 ED/APO complete	**5495.**

Packing & shipping in the 48 states: 4"--$105; 5"--$125; 6"--$185; 7"--$215.

#1697 Computer Drive System (CDS): Includes 4 dual-axis drive speeds (2x, 32x sidereal, 2°/sec. 8°/sec.); Smart Drive; keypad hand controller with digital readouts; GO TO capability from input RA and Dec or from 747-object library—**$695.** 8000-object CNGC library available separately at **$99.**

Meade ED/APO Optical Tube Assemblies and LXD 650 and 750 Equatorial Mountings are available for separate purchase; see the Meade General Catalog for details.

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how we could construct a permanent backyard shelter for our scopes. — *Eric J. McDowell, Vienna, Virginia*

— All observatory owners are invited to send us a short story about their design, how it was constructed, and the telescope it shelters. Please include photographs showing the stages of construction if possible. We'll publish these designs in an upcoming issue.

Not-So-Strange Cases

Kevin Krisciunas' humorous piece on eccentric astronomers ("Strange Cases!," November 1993) brought back many memories. As an undergraduate in astronomy in the 1950s, I worked with several such astronomers at the Harvard College Observatory.

Sergei Gaposchkin wasn't one of them. He was too normal. I found him to be extroverted, accessible, predictable, and at peace with himself.

If he ever said that he, Sergei Gaposchkin, never made a mistake, I dare say it was with a twinkle in his eye. *— Jeremy H. Knowles, Barrington, New Hampshire*

As a high school student in Vallejo, California, I had the pleasure of knowing T. J. J. See, who was a friend of my father's. In fact, Capt. See introduced me to astronomy, a field I'm still active in at age 82. I recall Capt. See as a pleasant man, although my father told me he was a controversial character. The one peculiar incident I recall was that one time while traveling from Mare Island to San Francisco on a Navy tug, some young Navy and Marine officers teased See, who responded with words of contempt. I don't know what set it off. — *Carlo E. Anderson, Kensington, California*

Tonight's the Night

Tonight was the first magnificently clear night in almost two weeks. That seems like a long time to a 12-year-old. I used my binoculars tonight because it is getting cold this time of year and they are easily portable. I must have seen millions of stars and hundreds of clusters. Right before I came inside, I saw a meteor flash overhead. I saw a total of 10 meteors. It was a great experience. Even though I am 12, I know a lot about space and enjoy your magazine. — *Jennifer Reilly, Hopkinton, Massachusetts*

Who Planned the Eclipse?

Just a note to say that your "Complete Eclipse Planner" (November 1993) isn't complete. You neglected the solar eclipse that will occur on May 10, 1994. Doesn't it count as an eclipse? Surely this eclipse should receive high billing in a "complete eclipse planner." Where is this information? — *Tom Butler, St. Ann, Missouri*

— Weather prospects for the May annular eclipse are covered in the issue you're holding; see page 74.

Tunguska Corrections

I want to correct a number of errors or omissions from my article on the Tunguska meteorite explosion (December 1993). Most importantly, the modeling of the 1908 Tunguska explosion was done with my colleagues Paul Thomas of the University of Wisconsin, Eau Claire, and Kevin Zahnle, of the NASA-Ames Research Center. It was not, by any stretch of the imagination, work that I did alone. The editors should not have introduced the pronoun "I" without mention of my co-authors.

I later applied our model to determine the fates of the newly discovered Spacewatch objects and found the small Spacewatch objects pose no significant threat to Earth's surface. We need not fear "Death from the Sky" from these objects, and I wish the editors had chosen a title consistent with the article's conclusions: The threat from small asteroids and comets is small.

The left-hand plot on page 42 contains several errors. Its horizontal scale should be in units of kilotons per km — how much energy each object delivers per kilometer of atmosphere it descends through. The labels on the curves incorrectly state why the model rules out certain objects as candidate explanations for the Tunguska event. All the candidates shown here explode with more-or-less the right energy to have been the Tunguska event. What distinguishes them is their explosion altitudes, given these energies.

Earth-crossing comets and asteroids do not typically hit Earth at 40 to 60 km/sec. Based on the statistics of the objects so far discovered, a typical Earth-crossing asteroid will strike at about 15 km/sec, and a typical short-period comet at about 25 km/sec. One way to picture the "pancaking" of the object is to imagine its front face decelerating due to the high pressure while its back end continues moving at high velocity. — *Chris Chyba, Washington, D.C.* ☐

ASTRONOMY welcomes suggestions and additional information about articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length and clarity.

So You Want to Be a Professional Astronomer?

by C. Renée Beveridge

"Pretend I'm a barmaid," said the burly, balding department chairman to the Ph.D. candidate. "Now tell me what you've done for seven years."

If it was difficult for the hapless candidate to envision the department chairman as a barmaid, it was even harder to describe, in layman's terms, what he had been working on.

I was a first-year grad student when I heard the story, and it seemed amusing at the time. I was still too bogged down in classwork to wonder if there was something wrong when a Ph.D. candidate couldn't explain his work to a barmaid.

Then one day, a non-astronomer friend asked me what I did at the big telescope in West Texas (the 2.7-meter at McDonald Observatory). I tried to explain spectroscopy, the galactic halo, and metal-poor dwarf stars, but she only smiled and nodded politely.

"Earth is the third planet from the Sun, right?" she finally asked. *Oh, dear,* I thought. *I have lost touch with the world.* I asked myself what got me into astronomy in the first place.

I remember becoming aware of the stars around fourth grade, absorbing the TV series *Cosmos* in fifth grade, and buying a 2-inch refractor in seventh grade. I spent many a night under the mercury-vapor haze of Houston peering at Saturn, Jupiter, double stars, and the Moon. I even helped my older brother with observations for his astronomy project in high school physics and I finished my own project before it was even assigned.

In college, I often camped in the Davis Mountains in West Texas, always taking a day to visit McDonald Observatory. To me, the huge white domes were mysterious places where super-intelligent beings cracked the codes of the universe. During one of those trips I decided to attend the University of Texas graduate school in astronomy.

Then grad school started. After deciding which sub-sub-subtopic of astronomy interested me, I began actual research for my master's degree. The topic? Loosely, it was galactic chemical evolution, a kind of galactic archaeology, if you will. Specifically, I was to study two stars with numbers for names in all the gory detail I could obtain from the 2.7-m telescope at McDonald and its new spectrograph.

It wasn't exactly an Earth-shattering endeavor, but it was a project to keep me occupied for a year. And I was finally going on a real observing run. I was enchanted with the idea of using the big scope, staying up all night collecting real data and, more importantly, running around the observatory with a set of keys to the place.

My first observing run was a blast. I felt so powerful standing on the dome catwalk peering down at the tourists. The night schedule took some getting used to, but I thought of it as an adventure. The occasional cloudy nights spent sitting in front of the television, downing beers and tortilla chips with salsa, were magical as well. I returned home from that run with renewed vigor. I was becoming a professional astronomer!

Then my advisor told me to do another observing run, this time by myself. No one to hold my hand; nobody to tell me to open the shutter of the spectrograph. Just me, flying solo. I was terrified. But that run also went superbly.

Then my advisor sent me on another run.

And another.

And another.

Somewhere amidst 10 observing runs in 10 months, I grew aware that I had spent those gorgeous West Texas nights inside a dome. I had peered at my two stars through the eyepiece when centering them, but I hadn't observed anything the way I had observed the moons of Jupiter back in junior high.

And more and more I realized I didn't like the new routine.

While working on my master's thesis, I took a few hours out to watch the Perseids. After sitting outside going "ooh" and "aah" with my husband and some friends, I forced myself to go inside. One friend then remarked, "So you have to stop stargazing to do astronomy, huh?"

Ouch.

I studied fellow astronomers and grad students to see if they shared my growing despair. I listened to colloquia that even other astronomers couldn't follow. I became less and less able to explain my work to my husband, and he was less and less interested. I began to dread observing runs. The icing on the cake came when I heard a fellow grad student gripe about an upcoming trip to Mauna Kea.

"Sure, it's Hawaii," he said. "But it's cold and there's so little oxygen you're dopey half the time, and the jet lag goes the wrong way."

I was flabbergasted. Professional astronomy wasn't supposed to be like this *at all.*

Finally, months of soul-searching told me that what I had fallen in love with as a child was not taking data, reducing data, re-reducing data, churning out paper after paper in unintelligible astronomer-jargon, writing observing proposals, writing grant proposals, and attending meetings.

No. What I loved was knowing about the sky and conveying a little of that knowledge to someone else. I loved standing in my backyard on a crystal clear December night and pondering the universe. I loved screaming, "Ooooooh!" when a meteor flashed overhead.

But I just couldn't bring myself to love the chemical compositions and radial velocities of two of the five known nitrogen-rich halo dwarfs.

I felt like Benedict Arnold when I told my advisor that I'd be leaving after my master's degree. We talked and talked about my decision and in the end he was fully supportive.

"You've got great potential as an astronomer," he said. "But if you don't love this with all your heart — get out!" He wasn't mean; he was just truthful. It made absolutely no sense for me to continue without the necessary passion.

So I left.

Even my parents wondered why I was throwing away a lifelong dream. But I've left the door open, for either a return to professional astronomy or simply keeping up with advances. All the same, I don't think I'll pursue professional astronomy again.

"You mean you love astronomy, but you don't want to be an astronomer?" you might ask. "That doesn't make any sense." But look at it this way: I love to tinker with a keyboard, but I'll never be a musician. You have to have the calling.

So if you find yourself wandering into professional astronomy and then realize that you aren't as enthusiastic about it as you once were, put aside the guilt pangs. It's not for everyone. And there's a lot to be said for not ruining a fine hobby by making it a profession. ☐

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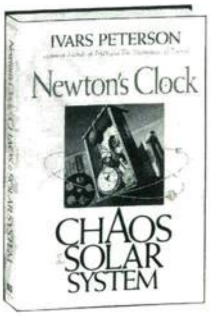
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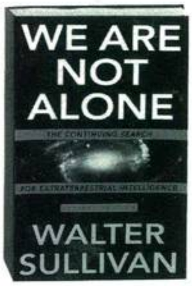
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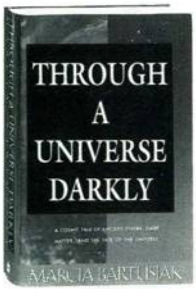
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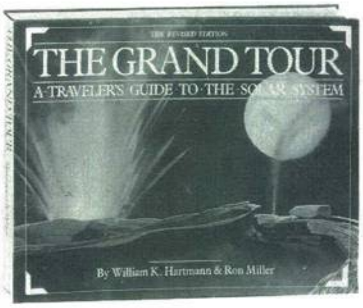
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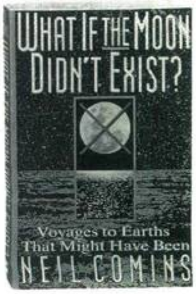
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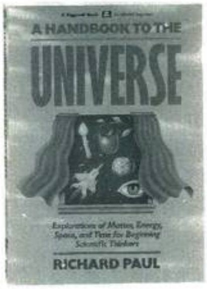
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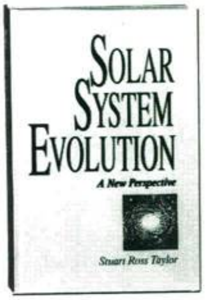
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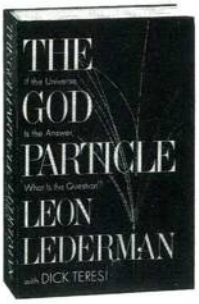
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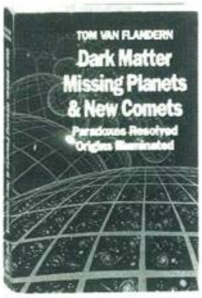
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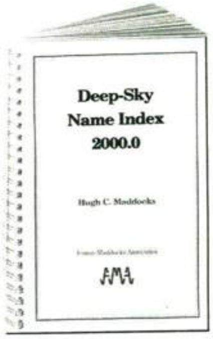
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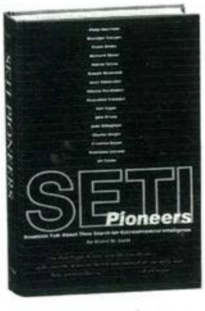
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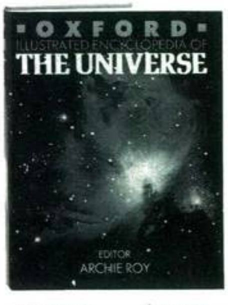
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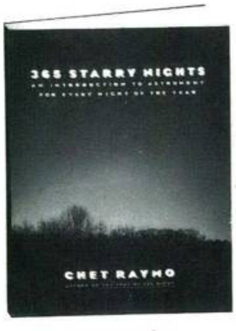
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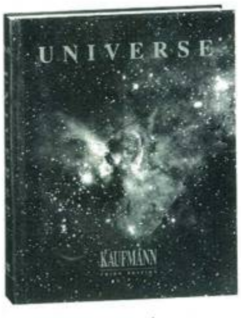
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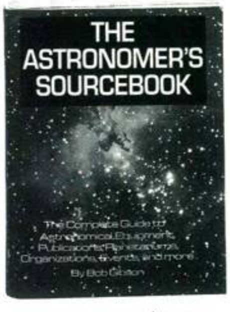
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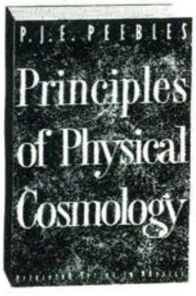
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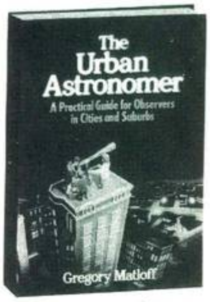
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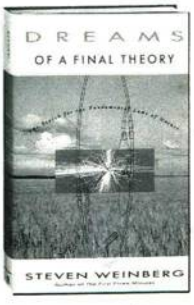
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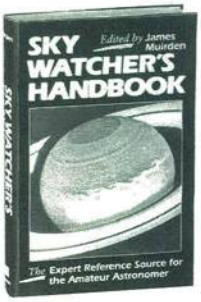
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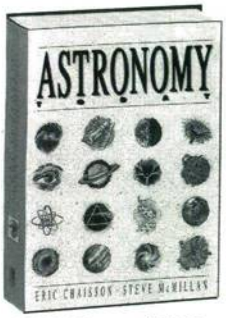
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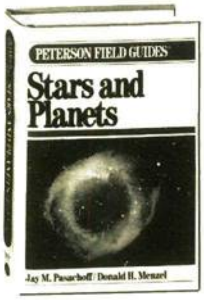
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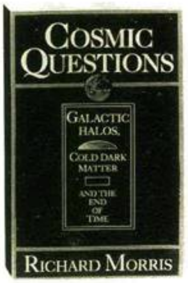
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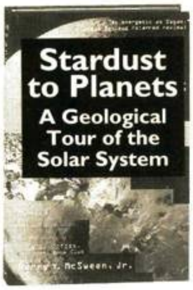
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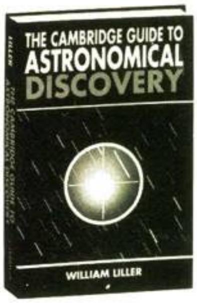
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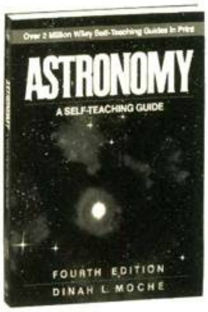
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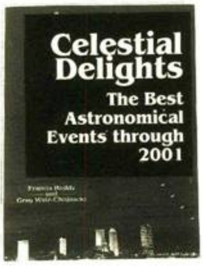
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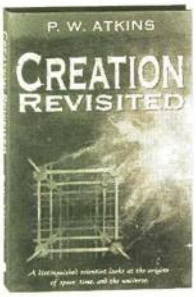
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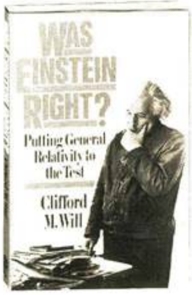
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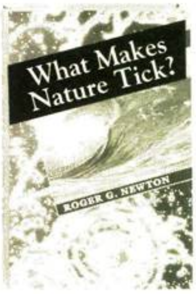
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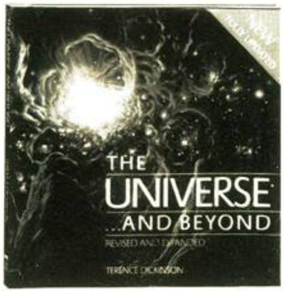
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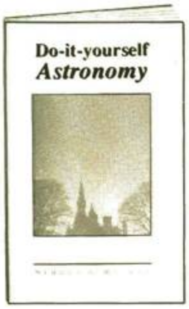
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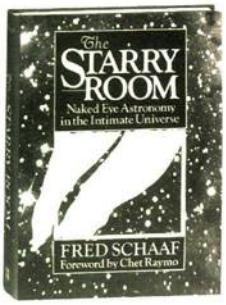
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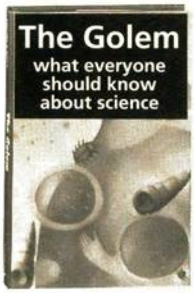
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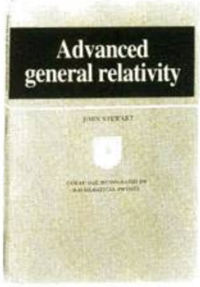
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Bang! Bang! Bang! Went the Comet

If a comet passes within about 2.7 radii of Jupiter, the immense planet's tidal forces will break it apart; this is what happened to Comet Shoemaker-Levy 9 back in July 1992. Now two scientists, Jay Melosh of the University of Arizona and Paul Schenk of the Lunar and Planetary Institute in Houston, have found evidence for other tidally broken comets (or asteroids) in Jupiter's past. The clue? Chains of impact craters stitched across two of its Galilean moons, Callisto and Ganymede.

Of the 12 chains found on Callisto, 11 lie on the moon's Jupiter-facing hemisphere and the 12th is just over the edge. Ganymede has only three chains, all on the Jupiter-facing side. (The probable reason Ganymede shows fewer chains, say Melosh and Schenk, is that its surface is younger.) Scientists originally attributed the crater chains to secondary impacts from unseen, larger craters. The amazing straightness and lack of source craters for these chains, coupled with the string-of-pearls appearance of Shoemaker-Levy 9, led Melosh and Schenk to propose their tidal-breakup model.

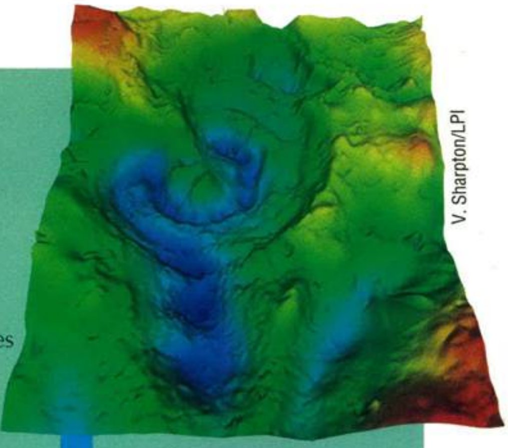
Most of the chains consist of craters in the 10-to-20-kilometer-diameter range, suggesting that the impacting fragments may be roughly uniform in size. And the close spacing of the craters strongly implies the impacts occurred immediately after the object broke apart, before the fragments could separate as the nuclei of Shoemaker-Levy 9 have.

Melosh and Schenk reported their results in the October 21 issue of *Nature* and at the Boulder, Colorado meeting of the American Astronomical Society's Division for Planetary Sciences.

Killer Crater Is Much Larger

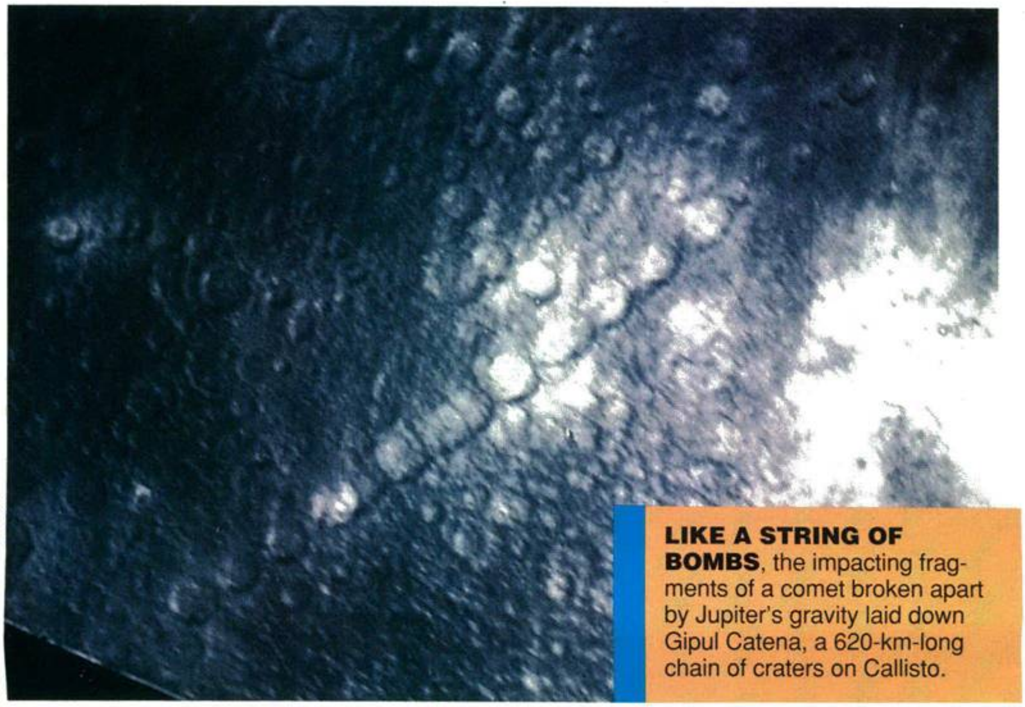
New gravity studies indicate that the Chicxulub crater, buried deep under the sedimentary rocks of Mexico's Yucatán peninsula, comes nearer to 300 km in diameter than the 180 km previously thought, says Virgil Sharpton of the Lunar and Planetary Institute in Houston. Sharpton headed an international team investigating the 65-million-year-old crater, which is widely believed to be the site of a "dinosaur-killing" impact at the end of the Cretaceous period.

If Chicxulub really is a 300-km impact basin, Sharpton notes, then it is one of the largest craters in the inner solar system. This would indicate that the Chicxulub impact was more extraordinary than scientists have previously thought. It also means the impact may have been big enough by itself to wipe out dinosaurs and other life forms, a point which some scientists have disputed on the grounds the crater originally seemed too small to produce the extinction.



V. Sharpton/LPI

DINOSAURS' DEADLY BULL'S EYE. Circular rings mark variations in gravity over the Chicxulub crater in this artificial-relief view. A new study indicates that the crater, formed 65 million years ago, is about 70 percent larger than scientists had thought.



LPI/NASA from Paul Schenk

LIKE A STRING OF BOMBS, the impacting fragments of a comet broken apart by Jupiter's gravity laid down Gipul Catena, a 620-km-long chain of craters on Callisto.

Manson Didn't Kill Dinosaurs

For the past several years, the buried impact crater at Manson, Iowa, has been a minor suspect in the mystery of dinosaur extinction 65 million years ago. No longer. A team of researchers led by Glen Izett of the U. S. Geological Survey in Denver has conducted new field work at the 35-km-wide crater, which lies buried under about 300 feet of glacial debris in central Iowa.

Their studies, using minerals that preserve their potassium-argon radioactive dates better than those used in previous studies, show that the Manson crater formed 73.8 million years

(continued on page 20)

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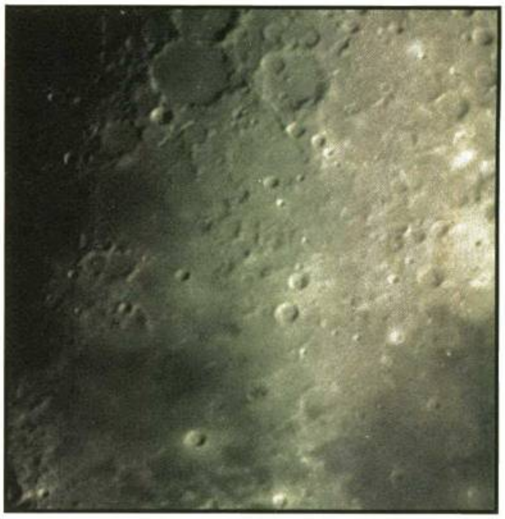

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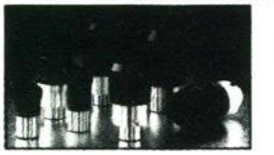

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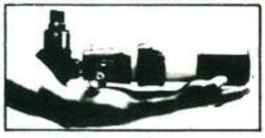

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ago. That's almost 9 million years before the colossal event that ended the Cretaceous period in a mass extinction.

The new date leaves the Chicxulub structure in Mexico's Yucatán as the only known crater dated exactly at the Cretaceous-Tertiary (K-T) boundary. However, Chicxulub's newly revised size (see previous news story) appears to make it more than adequate to explain the K-T mass extinction.

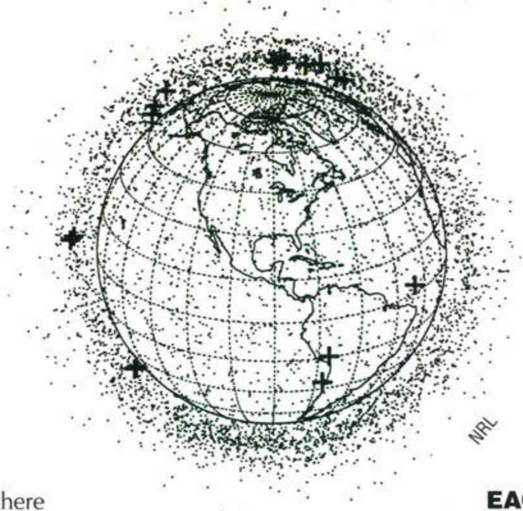
The new date for Manson may also help solve a different puzzle. A South Dakota rock layer called the Crow Creek Member is full of sand and broken shale bits, very unlike the quiet-water shales that lie immediately above and below it. Crow Creek's date is about 74 million years. The team speculates that the Manson impact may have triggered a tsunami, a tidal wave, which stirred up the shallow ocean then covering South Dakota and laid down a layer of crater ejecta and other disturbed material.

Space Junk Explodes in Number

At the 1993 European Space Debris Conference, experts estimated that about 7,000 objects, such as non-functioning satellites, spent rocket boosters, and fragments of spacecraft, now orbit Earth. But researchers say now there could be over three times this amount circling the Earth.

Naval Space Command, the group responsible for monitoring and cataloguing all objects in space, is able to track smaller bits of debris, using the new Connection Machine supercomputer at the Naval Research Laboratory. If they catalogue all objects down to one centimeter in size, the list of Earth-orbiting debris could include up to 25,000 objects.

The new supercomputer not only tracks these targets, but also calculates when any come close to a working satellite. Researchers relay notices of close approaches to the Air Force Space Command telescope on Haleakala in Hawaii. During a recent experiment, they videotaped the close approach of two weather satellites that passed within two km of each other.



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EACH DOT SHOWS THE LOCATION of a satellite or piece of space debris on September 25, 1993. The crosses indicate objects within 10 km of each other.

Miranda: Seeing Its History Afresh

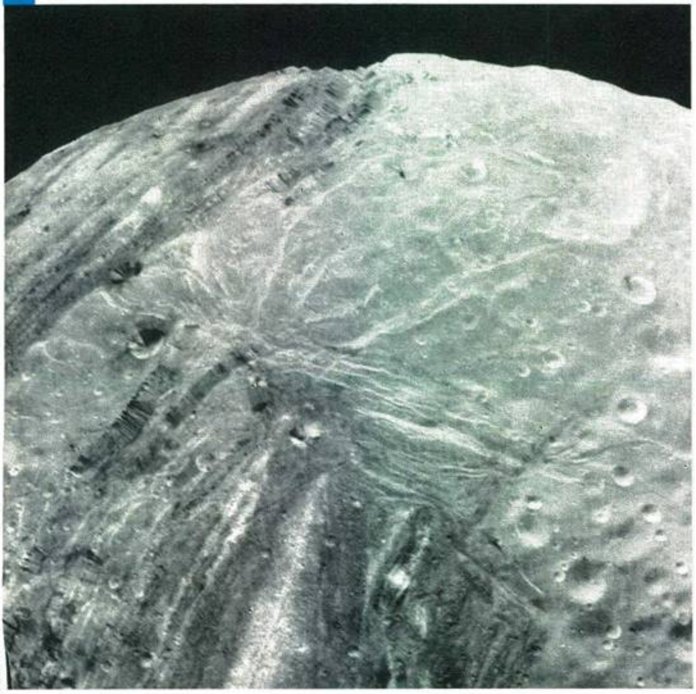
Explaining the contorted geology of Uranus' small icy moon Miranda has challenged planetary scientists ever since the Voyager flyby in 1986. Many have come to believe that the moon we see today is the outcome of a catastrophic breakup and reassembly.

However, planetary geologists Robert Pappalardo and Ronald Greeley of Arizona State University now suspect that Miranda's surface reflects mostly internal forces. In particular, they say, the coronae (oval "racetracks" of ridges and grooves) mark giant areas of upwelling possibly driven by heat created by the uneven pull of Uranus' gravity early in the moon's history.

Key details lie in the ridges and grooves at the edges of the coronae. In the standard smash-and-reassemble history for Miranda, these features form as heavier pieces sink toward the moon's core and set up currents that compress the surface above them. But by taking a more detailed look at the coronae, Pappalardo and Greeley have identified fault valleys, icy lava flows, streaks on the ridge faces, and slumped blocks of ground that have rotated backward like dominoes. These they interpret as the result of faulting that happened when rising convection currents within Miranda pulled the ground apart.

Besides explaining the surface better, Pappalardo and Greeley say the new model offers a better chance to investigate Miranda's early interior history, now frozen in place.

FROM OUTSIDE OR WITHIN? There is new evidence that the ridged terrain on Uranus' moon Miranda was produced by internal heating rather than a violent breakup and reassembly of the moon.

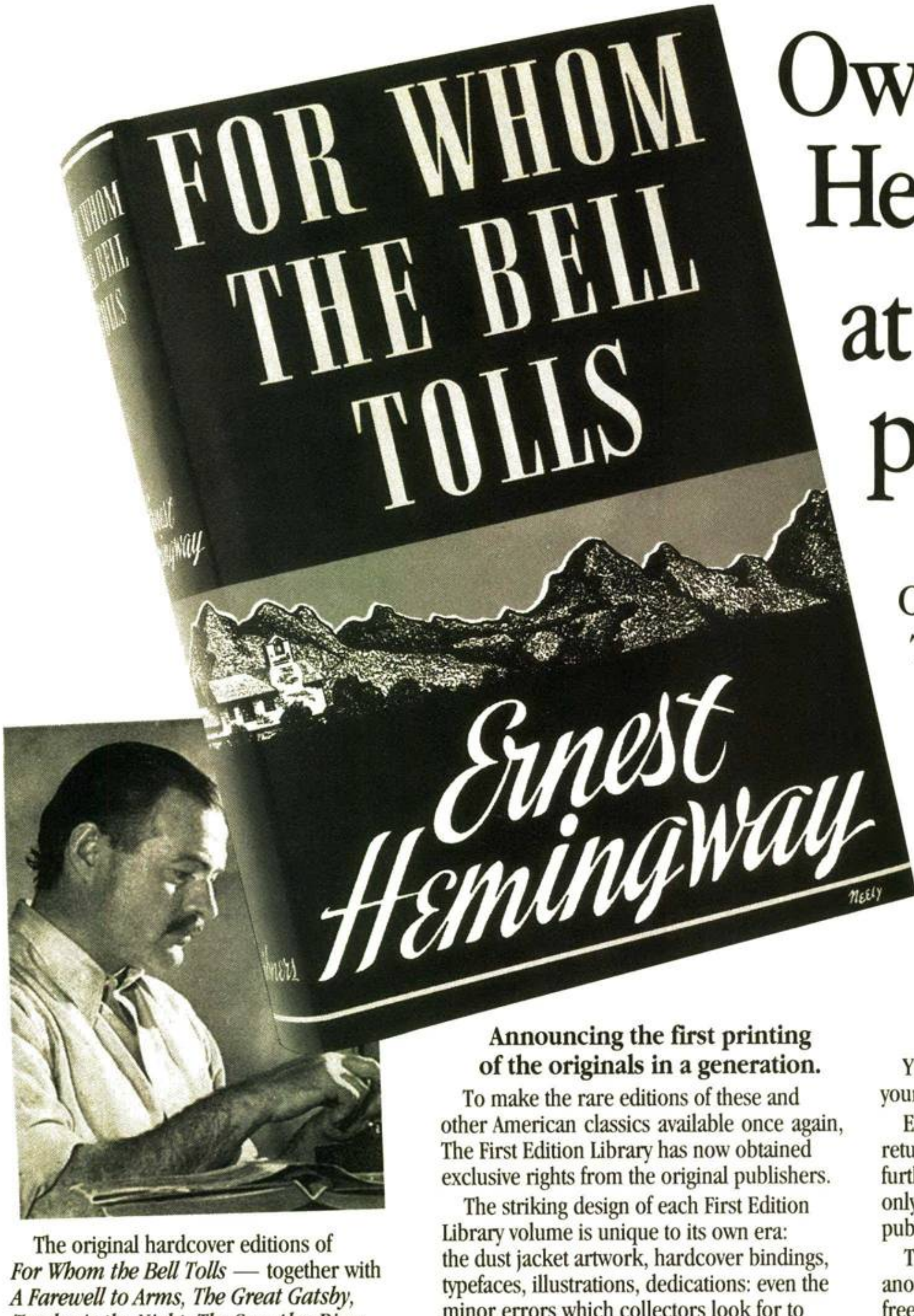


Arizona State University

Space Dust in Your Eyes

Forty thousand tons a year. That's how much meteoritic dust and debris fall on Earth, according to two scientists working with NASA's Long-Duration Exposure Facility (LDEF). Stanley Love and Donald Brownlee of the University of Washington studied the damage done to the massive satellite, which spent about six years in Earth orbit (see "Motes in the Solar System's Eye," May 1993). They published their results in the October 22 issue of *Science*.

The greatest amount of meteoritic mass arrives in the form of particles around 200 micrometers in diameter, but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the particles recorded by LDEF ranged from 10 to 500 micrometers in size. Love and Brownlee note that while the amount of dust they found is somewhat higher than scientists had previously estimated, it agrees closely with geochemical evidence found in ocean sediments and other deposits.

Looking Below Mercury's Surface

New maps made at radio wavelengths of the surface of Mercury show that it is much lower in iron and titanium than the surface of the Moon. Astronomers expected to find substantial amounts of iron and titanium because their current models indicate that a giant impact tore off much of the innermost planet's surface, leaving behind a dense iron core. The observations made by David Mitchell and his colleagues at the University of California at Berkeley will make it a challenge for astronomers to come up with new ideas about why Mercury has an unusually high density but little iron at its surface.

Firing Rockets at Asteroids

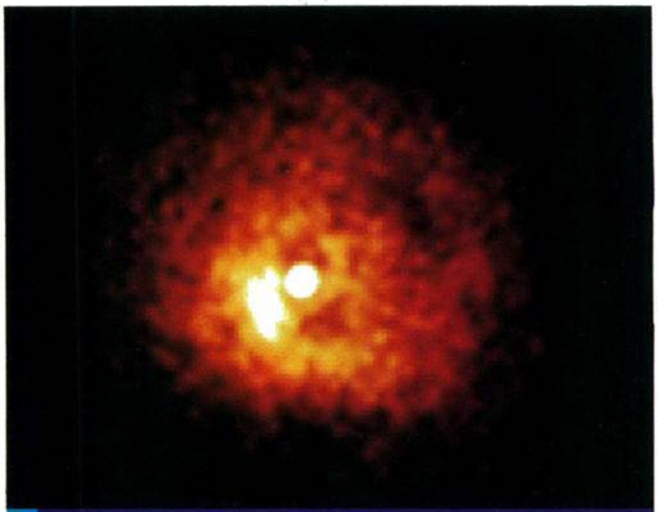
A unique space mission has been proposed by the Ballistic Missile Defense Organization (formerly called the Strategic Defense Initiative Organization, or "star wars" group). Here's the plan: Equip a small spacecraft with four projectiles and launch it toward two asteroids. At closest approach, fire two projectiles at each asteroid and watch the debris that is knocked loose using high-tech sensors on board the carrier craft. Thus we learn what the asteroids are made of. Sound crazy?

The mission, called Clementine 2, makes use of four missile-killer devices called LEAPs (Light ExoAtmospheric Projectiles) and hardware left over from the Clementine 1 mission, a joint program of the Ballistic Missile group and NASA. Clementine 1, set for launch on January 24, will orbit the Moon for two months before flying off for an encounter next August 31 with the near-Earth asteroid Geographos (see page 34 for details). Clementine 1 was built in two years following the "faster, cheaper, better" philosophy now being embraced by both the military and NASA. Officials with the Ballistic Missile organization estimate Clementine 2, complete with four LEAP penetrators, could be launched within two years for less than $35 million.

Satellite Hit by Perseid?

On the night of August 11/12 the European Space Agency's Olympus satellite began spinning out of control for no apparent reason. Launched in 1989, the 5,700-pound communications satellite has served as a testbed for new communications technologies. The coincidence of the mishap with the peak night of the Perseid meteor shower has prompted speculation that Olympus was hit by a meteoroid. However, from the initial data ESA technicians could not prove a meteoroid was the culprit.

After the mishap, ESA controllers used the last fuel to move Olympus out of geostationary orbit so it would not clutter an already densely populated area of space. Olympus was then shut off, a year before the planned end of its mission.



A. Edge (Cambridge University), et al.

X RAYS POUR from the Perseus galaxy cluster but not from areas of intense radio emission, confirming astronomers' expectations. The bright central region in this X-ray image from ROSAT is NGC 1275 (Perseus A), an active galaxy that also emits strongly at radio wavelengths. The diffuse radiation surrounding NGC 1275 comes from intergalactic gas heated to temperatures of ten million degrees. The regions of weak X-ray emission just north and south of the central galaxy coincide with the strongest emission from NGC 1275's radio jets. The jets presumably clear those areas of hot gas. Although radio astronomers had long predicted such an effect, this is the first X-ray image detailed enough to prove it.

Lowly Metal Found in Space

The heaviest metal found in space so far is . . . tin. Despite its rather ignoble standing on Earth, this base metal has presented researchers with a clearer idea of how

AFTER 11 MONTHS IN SPACE, the European Space Agency's EURECA satellite was pulled into the shuttle Endeavour's cargo bay last summer and returned to Earth. Among EURECA's 18 experiments was an X-ray telescope called WATCH, the Wide Angle Telescope. WATCH continued to make observations right up until the last day of the mission, scanning the sky for sources of cosmic gamma rays and X-rays.

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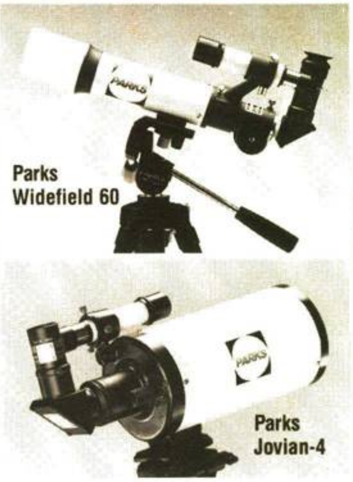

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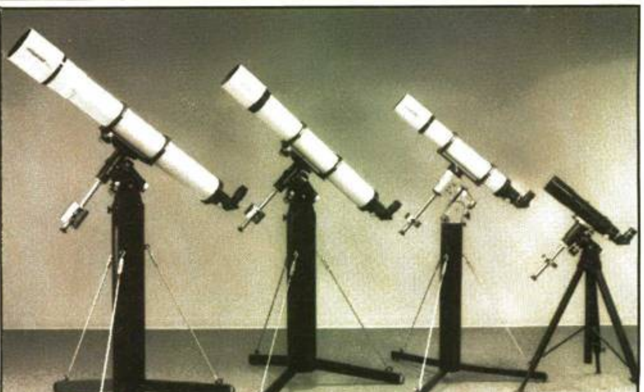

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The new STARFIRE EDT arrived a few days ago. It was a joy to unpack it and to set it up: it looks beautiful and bears testimony of exquisite craftsmanship throughout. Yesterday the sky cleared up and the telescope got first light. I was out under the stars for many hours — looking, testing and also comparing the new instrument with other telescopes. Yet I soon realized that there was no reason to use any other instrument: the STARFIRE simply was superior. Deep sky views were sharper, cleaner and more contrasty than I have ever seen. And best of all: with this instrument the problem of spurious color definitely is gone — incredible! Jupiter was quite a show at all magnifications I tried. What amazed me was how bright its disc looked even at high magnification, with the colors in the belt system readily visible. There was a wealth of detail, much more than I could have drawn: it was a totally satisfying night of observing. Thanks for a superb instrument."

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interstellar gas condenses to form solid grains. Lewis Hobbs of the University of Chicago and his team of astronomers detected the presence of tin in interstellar gas using the Goddard High Resolution Spectrograph on the Hubble Space Telescope. The group believes the grains form in stellar winds, the high-speed streams of hot gases and high-energy particles ejected by stars. The gases cool as they move away from the stars, permitting grains to condense in some regions. Tin joins other heavy elements previously found in interstellar space such as copper, gallium, and krypton. Hobbs and his fellow researchers will continue searching for other metals.

Minor Planet Society Formed

To promote public awareness and generate private funding of near-Earth asteroid research, astronomy enthusiasts can now join the Minor Planet Society, a new non-profit organization formed as part of the World Space Foundation. Funds raised by the society underwrite the asteroid survey being conducted by Eleanor Helin of the Jet Propulsion Laboratory, a project that to date has discovered hundreds of main-belt asteroids as well as 75 near-Earth asteroids. For more information, call (800) 638-3672 or write to the Minor Planet Society, Inc., P.O. Box 31313, Palm Beach Gardens, FL 33420.

AMATEUR NEWS

League Presents Young Astronomer Awards

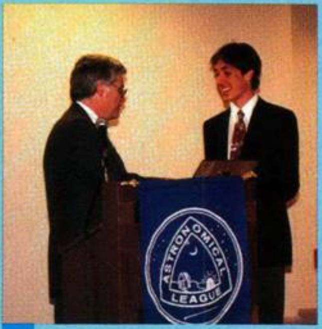
After a hiatus of over 25 years, the Astronomical League has reinstated its Young Astronomer Award. The last such award was given in 1966 when the League recognized the work of a young J. Richard Gott, now one of the world's leading cosmologists.

The 1993 winners received their awards on July 31 at the League's national ALCON meeting held in Madison, Wisconsin. Blake Warren Thomas, 18, of Edgewood, New Mexico, received top honors for his research with a diffraction grating spectrograph he built for his 8-inch reflector.

Stephanie Cinereski, 16, of Gainesville, Florida, won second place honors with her five-year study of the solar sunspot cycle and the latitude of solar sunspot eruptions relative to solar maximum.

Third place went to Katrina Koski, 18, of Grosse Pointe, Michigan, who devoted more than 4,000 hours to the design and construction of an 18-foot radio telescope at her high school.

The National Outstanding Young Astronomer Award is open to all U. S. residents who are in high school or of high school age and not enrolled in college. For details, contact Charles Allen, Award Chair, 1007 Rollingwood Lane, Goshen, KY 40026, or call (502) 228-3043. — *Charles Allen*



Charles Allen

OUTSTANDING YOUNG ASTRONOMER Blake Warren Thomas receives the Astronomical League's top award from president Jim Fox at the League's national convention held in Madison, Wisconsin.

Bringing Kids and Scopes Together

"All kids want to do today is watch MTV and play Nintendo. They're not interested in astronomy." So goes an often-heard assessment of the state of science education in the '90s. But two grass-roots programs are dispelling this myth and are putting hundreds of telescopes into the hands of enthusiastic students and teachers.

Striking Sparks

The Sonoma County Astronomical Society (SCAS) in Northern California has completed its fifth year of an ambitious public education program called "Striking Sparks." As part of the project, members of the SCAS visit schools and youth organizations to present talks. After each talk club members conduct a star party, weather permitting. Students, teachers, leaders, friends, and family are all invited.

The club's largest science education activity is its telescope award program. Each year the club awards at least 10 telescopes to Sonoma County students from grades K through 12. To be considered for a telescope, students write essays using the general heading "Why I would like to have a telescope."

The telescopes are simple Dobsonian reflectors using 5.5-inch f/7 mirrors. SCAS members Bob Ferguson and Larry McCune manufacture the telescopes with the aid of other SCAS members on special "Sparks" assembly days. The club funds the program through support from local companies and individuals.

Organizations wanting to implement similar programs are invited to contact the Sonoma County Astronomical Society at P.O. Box 183, Santa Rosa, CA 95402. — *Ed Megill*

IOMEGA's Astronomy Enrichment Program

Over 160 six-inch telescopes in thirteen months! This sounds like the output of a small factory, but instead it is the result of IOMEGA Corporation's Astronomy Enrichment Program. To encourage the study of science, IOMEGA has so far donated dozens of telescopes to rural schools in Utah, Idaho, and Wyoming.

The 6-inch reflector telescopes are checked out from the school much as a book can be checked out of the library. Each school receiving a telescope designates a teacher to attend a two-day workshop on telescopes and observing techniques.

Two IOMEGA employees and amateur astronomers, Brent Watson and Wayne Sumner, operate the program. IOMEGA donates the staff time as well as funds for building the telescopes. For information on how you can implement a similar program, contact the author at (801) 778-1000. — *Brent Watson*

FOR SALE. *Amateur Telescope Making*, book one, fourth edition, 1964. In very good condition; $45. Contact Ray (608) 233-4799.

WANTED. Good, small, portable telescope. Contact Ray Marion, P.O. Box 620534, Middleton, WI 53562. (608) 233-4799.

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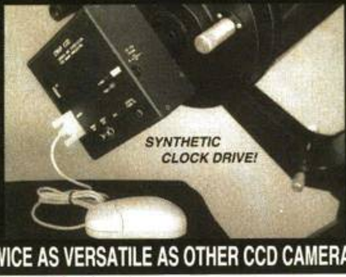

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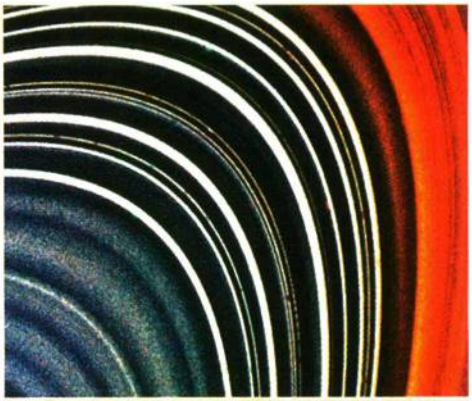

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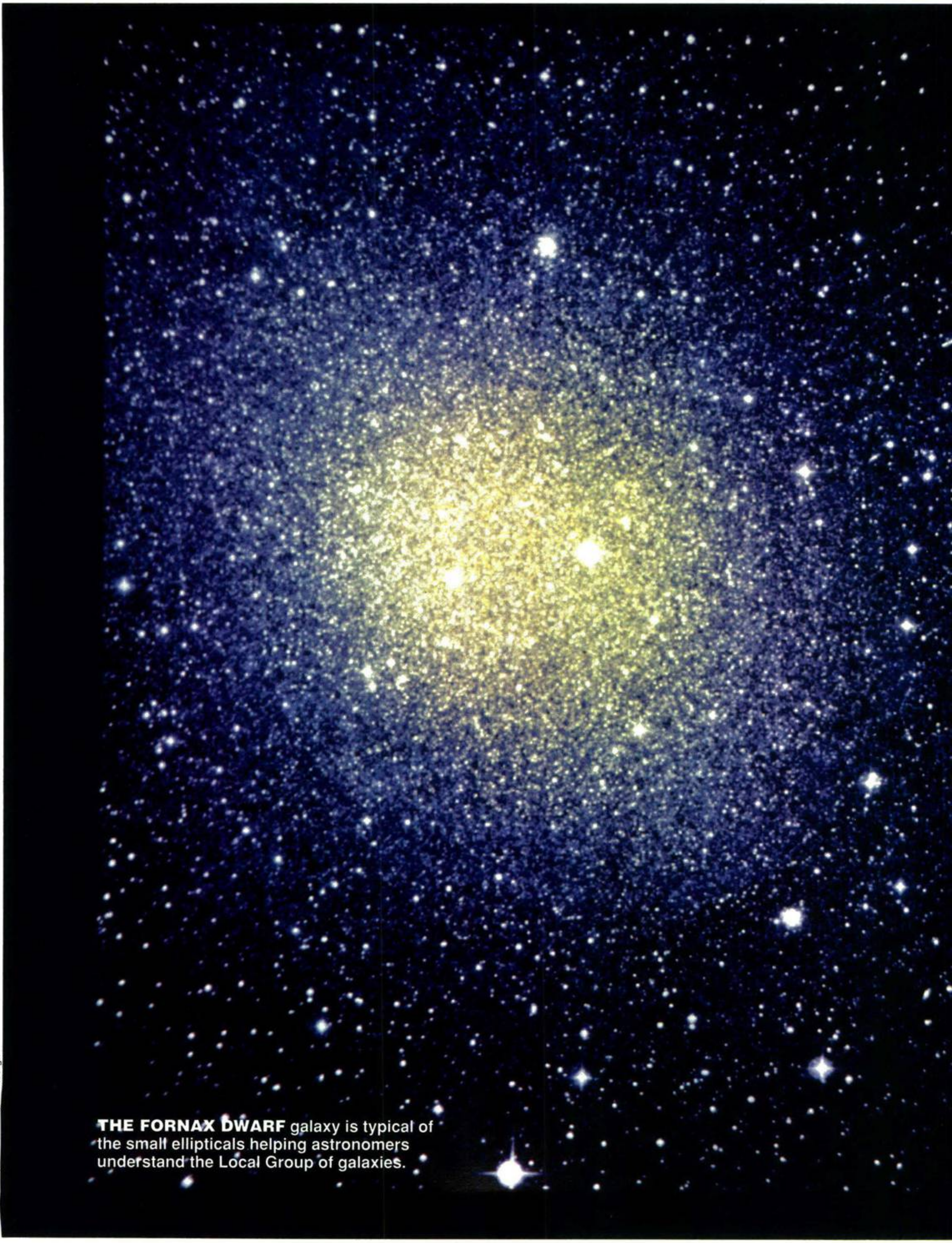


THE FORNAX DWARF galaxy is typical of the small ellipticals helping astronomers understand the Local Group of galaxies.

UK Schmidt/Royal Observatory, Edinburgh

Our New! Improved! Cluster of Galaxies

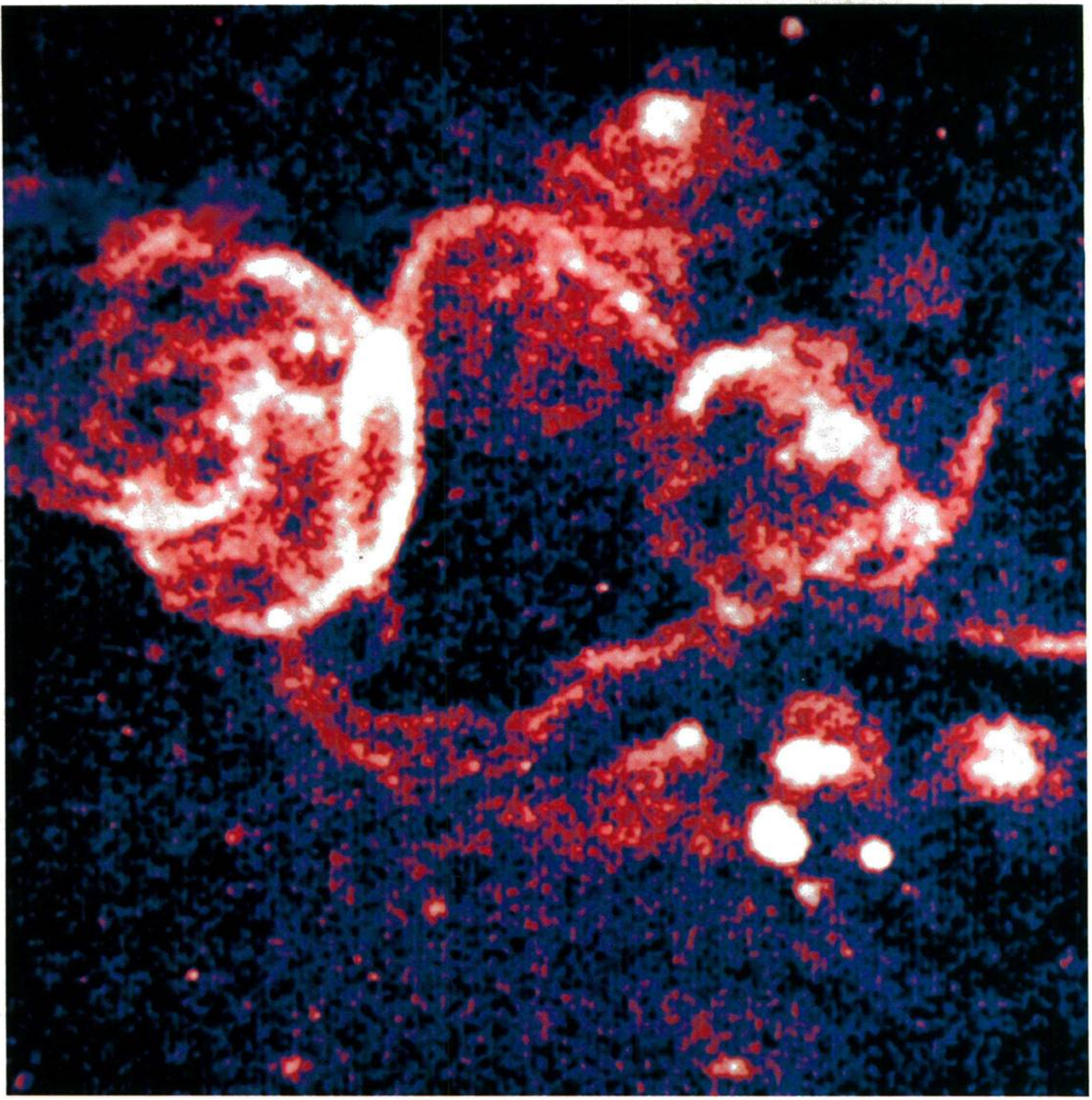
Dwarf galaxies in the Local Group are painting a new picture of our galaxy cluster and the universe that surrounds it. Thanks to discoveries of galaxy collisions, plentiful dark matter, and rapid-fire star birth, we'll never see the universe in quite the same way.

by Paul Hodge

Our Local Group of galaxies is a little like a large family. There are a few big, massive members — the adults — surrounded by many smaller members — the children. Some of the children are noisy and some are quiet. Some stay close to the adults and some scatter out almost into the neighbors' yards.

The big, massive members of the Local Group family are the three spirals: our Milky Way, the Andromeda Galaxy, and M33. The little members are the dwarf galaxies, nearly 30 of them. Among the largest dwarfs are the Magellanic Clouds, which stay close to the Milky Way. The Andromeda Galaxy also has two small members clinging to it, the elliptical galaxies M32 and NGC 205. Several even smaller dwarfs orbit the giants. But many of the little members of the family whiz around, unattached and independent.

The group stretches four million light-years across, but most of the largest of these dwarf galaxies lie within



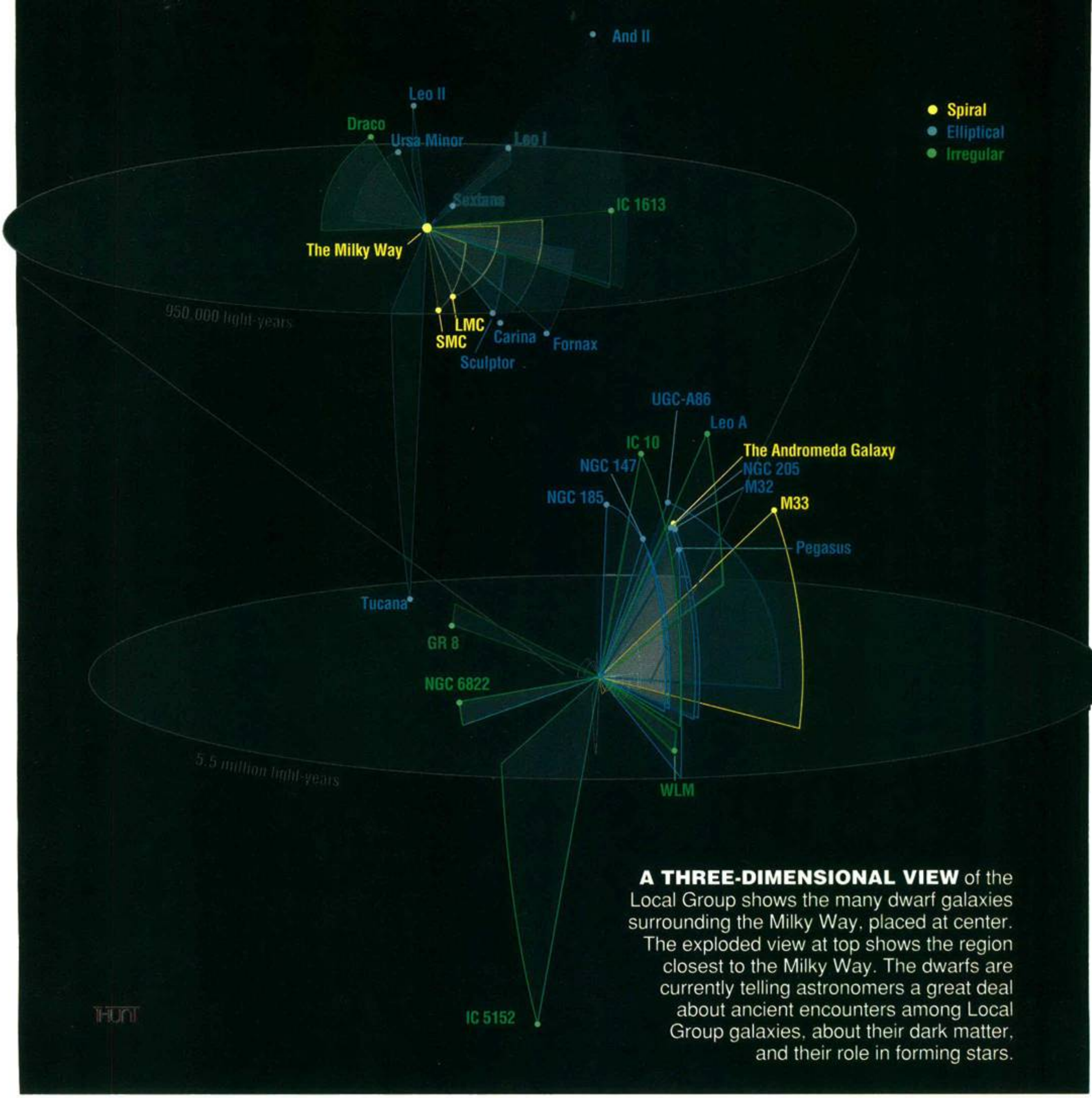
Kitt Peak National Observatory

RINGS AND BUBBLES OF GAS collectively called Sandage 10 live in the dwarf irregular galaxy IC 1613. A succession of supernovae caused this peculiar chain of structures. These supernovae may trigger periods of star formation in galaxies like IC 1613 and other irregulars and dwarfs in the Local Group.

the central two million light-years. We consider this a group because the galaxies share a common motion in the cosmic sea and because the nearest concentrations of galaxies are several million light-years more distant. The shining stars are the group's three big spirals, the Andromeda Galaxy, M33, and our own Milky Way. The quiet ones are the rest of the galaxies, 29 in all, a cloud of dwarf ellipticals and irregulars, that hovers around the central spirals.

For years astronomers have fixed their gaze on the great spirals, the Andromeda Galaxy and the Milky Way, along with the slightly smaller spiral M33. The big galaxies are close (so close we live in one of them) and show the full range of galactic activities. So what could serve better as a laboratory for exploring the inner workings of all galaxies in the universe? These magnificent wheels of stars could tell us everything about how galaxies behave. *Or so astronomers thought.*

But now it's the dwarf galaxies, the ones tucked away from the spotlight, that appear to hold clues to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5.5 million light-years
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HUNT

A THREE-DIMENSIONAL VIEW of the Local Group shows the many dwarf galaxies surrounding the Milky Way, placed at center. The exploded view at top shows the region closest to the Milky Way. The dwarfs are currently telling astronomers a great deal about ancient encounters among Local Group galaxies, about their dark matter, and their role in forming stars.

ASTRONOMY: Thomas L. Hunt

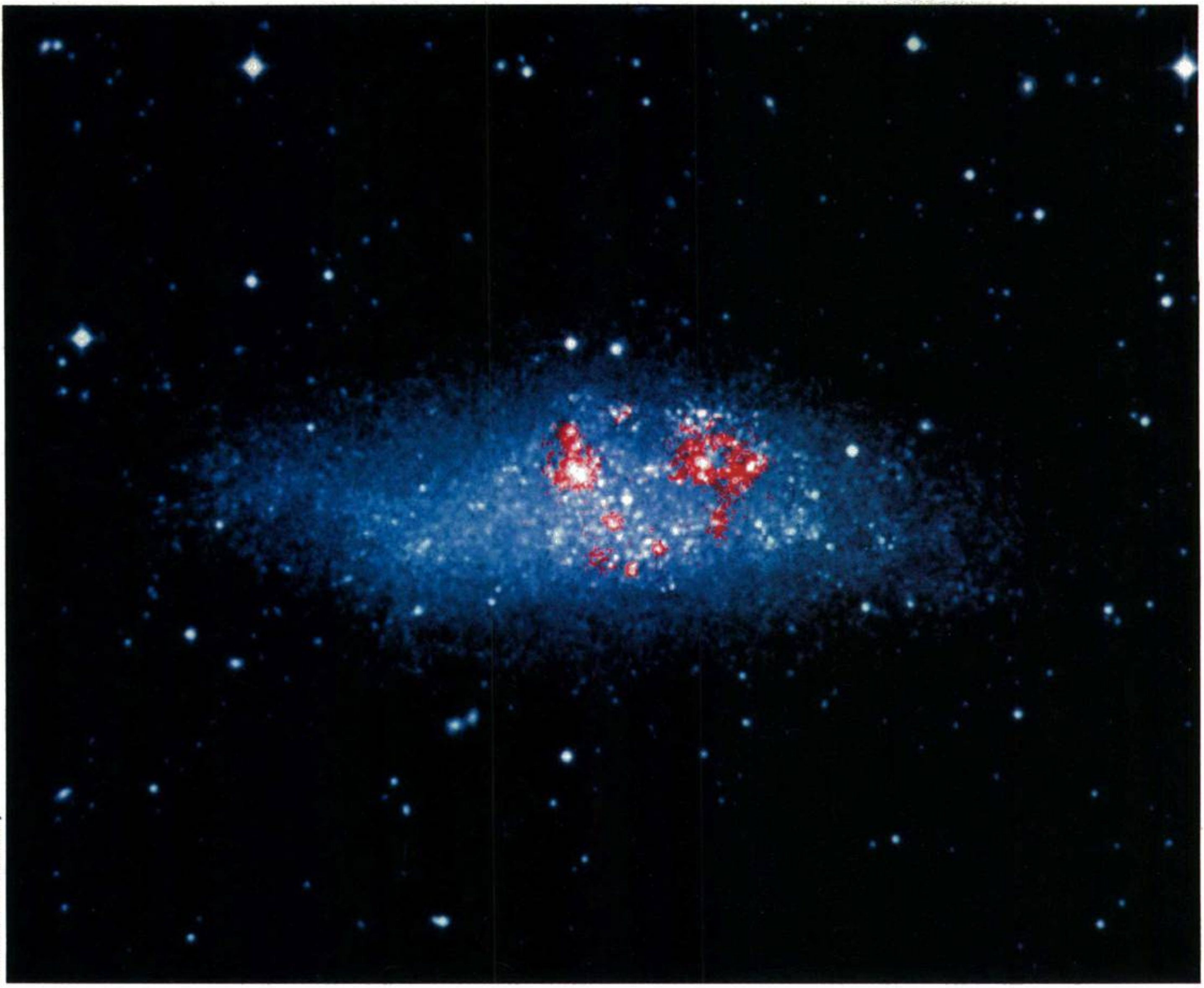
understanding three characteristics of Local Group galaxies. First, remnants of ancient dwarfs tell us about old interactions among Local Group members, interactions that show astronomers how galaxies within groups behave over long periods. Second, the amount of dark matter surrounding dwarf galaxies offers a clue to the amount of dark matter in the entire universe and a measure of the universe's fate. Third, the discovery that dwarfs in the Local Group go through intense periods of forming stars may revolutionize our ideas of how galaxies throughout the universe evolve.

To astronomers, these breakthroughs confirm the importance of the dwarfs in the Local Group. The dwarfs are close, which lets us see them in magnificent detail, and we can apply our knowledge of these dwarfs to other, more distant dwarf galaxies in other groups and clusters. This allows us to begin to draw broad conclusions about galaxies and galaxy clusters clear across the universe. Such is the blessing of living in an average group of galaxies — most of the universe is made up of average groups of galaxies.

Two Galaxies That Pass in the Night

Some dwarfs orbit the big spirals just as moons orbit planets. Studying the way they orbit the big spirals can tell us about the Local Group as it was billions of years ago and the way it will be billions of years from now. This, in turn, hints at the way galaxy groups and clusters evolve over very long time scales. How do their galaxies move relative to each other? Do galaxies collide with each other or just pass like ships in the night? Could collisions supply inert galaxies with ample gas and dust with which to make stars? These questions lie at the forefront of galaxy research. Because dwarfs offer the answers to so many key questions, astronomers now search for them diligently.

The search for dwarfs that are orbiting larger galaxies has led to a widespread survey of the motions of



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AN OUTLYING DWARF of the Local Group called WLM (short for Wolf-Lundmark-Melotte) consists of a cloud of blue stars speckled by glowing red clouds of hydrogen gas. The blue stars are young, massive, hot stars that prove the galaxy is actively forming stars.

galaxies in the Local Group. Knowing the motions will help us understand how the galaxies interact with each other over long time periods. In 1993 Gene Byrd of the University of Alabama discovered that two galaxies just outside the Local Group, Maffei 1 and IC 342, appear to be speeding away from the Andromeda Galaxy. (See "Intruder Galaxies," November 1993.) Tracing the motions of the galaxies backward shows they must have collided with the Andromeda Galaxy about five billion years ago. Byrd hypothesizes that in the encounter two pairs of galaxies approached the Andromeda Galaxy. Two of the galaxies, possibly dwarfs, spiraled into the Andromeda Galaxy. The two survivors, Maffei 1 and IC 342, are the ones speeding away. In addition, the encounter may have sent the dwarf elliptical galaxy Leo I toward the Milky Way. Such encounters change the dynamics of the Local Group and probably add material to dwarfs, enabling these otherwise sterile galaxies to produce new stars.

Just a few months after Byrd announced his findings, another study seemingly confirmed Byrd's hypothesis. Tod Lauer of Kitt Peak National Observatory and 15 colleagues found more solid evidence for the ancient interaction. Using the Hubble Space Telescope, the astronomers imaged a double nucleus in the Andromeda Galaxy. One of the two nuclei, Lauer believes, consists of material cannibalized by the Andromeda Galaxy during the encounter. The episode suggests that mergers play a significant role in the way galaxies evolve.

The current research on the motions of dwarfs may also have significance for astronomers studying larger elliptical galaxies. Astronomers know that mergers alter the lives of Local Group galaxies. They know that mergers alter the lives of galaxies in other groups. Some astronomers, in fact, believe that elliptical galaxies can form from the mergers of spirals. Last year Stephen E. Zepf of the University of California and Keith M. Ashman of the University of Kansas reported observations of two distinct ages of globular clusters in two distant elliptical galaxies, Centaurus A and M49. Zepf and Ashman propose that a new, younger set of globulars formed when the galaxies collided with nearby galaxies and that young globulars are the smoking gun that may lead to discoveries of other merged galaxies. The implications for galaxy mergers' triggering star birth in galaxies are far-reaching. Later, we'll investigate this in greater detail.

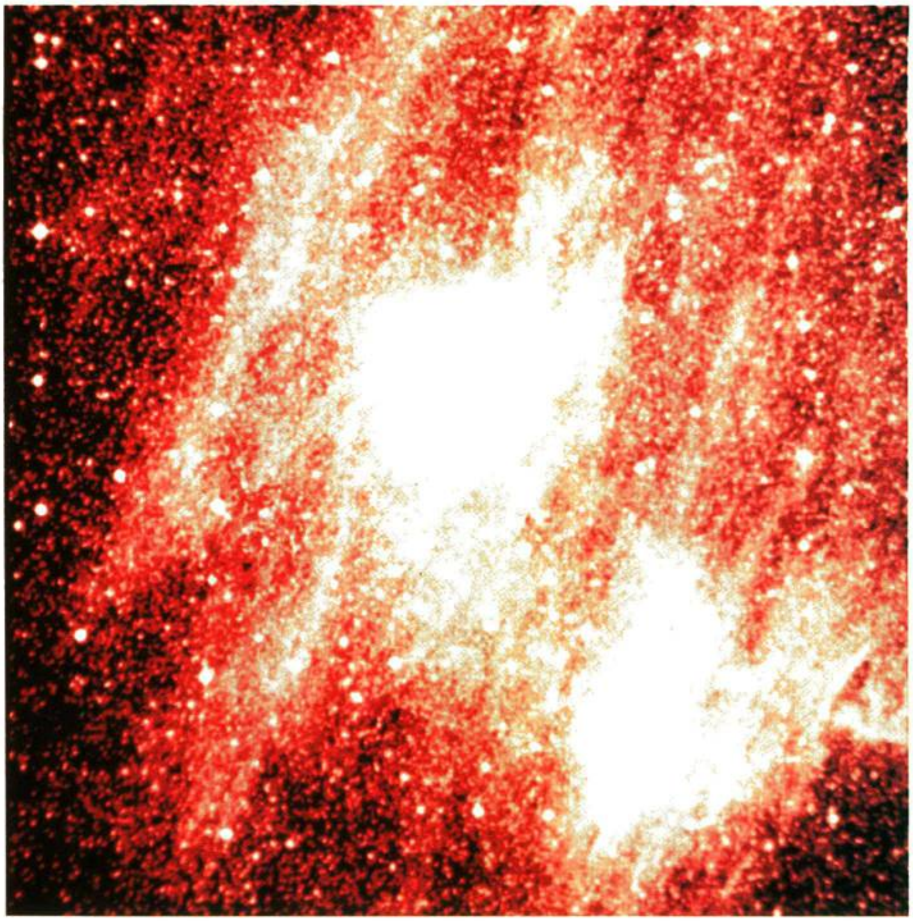
Studying the motions of Local Group dwarfs has led to another unexpected discovery, one that adds greatly to the research of Byrd and Lauer because it views not the past but the future of the Local Group dwarfs. Last year Douglas N. C. Lin of the Lick Observatory reported on a measurement of the proper motion, the movement as we see it across the sky, of the Large Magellanic Cloud, one of our Galaxy's irregular satellites. Because Lin also knew the LMC's radial motion, its movement along our line of sight, he could calculate the true motion of the galaxy in space. Lin confirmed that the LMC is orbiting the Milky Way and demonstrated that it has circled our Galaxy five to eight times since forming. Lin was startled to discover the LMC will not last forever. The gravity of the Milky Way will tear it apart, scattering its stars and clusters among the spiral arms of the Milky Way. The LMC has less than 10 billion years to live.

Astronomers like Byrd, Lauer, and Lin are showing that we can use dwarf galaxies to probe the ancient history of the Local Group and begin to predict its future. They are beginning to see that encounters and mergers may play significant roles in the lives of galaxies, destroying them, adding material to them, or perhaps even giving them the ability to make new stars, making them fertile once again. Using the dwarfs as examples, we can look deep into the universe and see similar things happening.

Things That Go Tug in the Dark

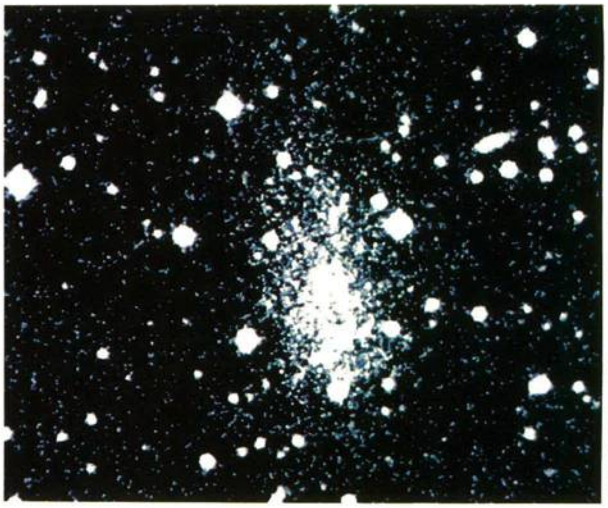
Fortunately we don't need to wait for galaxies to collide to discover things from them. Dwarf ellipticals in the Local Group offer a unique laboratory for astronomers studying dark matter. Because the galaxies are so close, they are relatively bright, allowing us to take high-quality spectra that show us their internal motions.

Last year at a conference at the Observatoire de Haute Provence in France, Mario L. Mateo of the University of Michigan summarized the spectral data. He and others have measured velocities of stars in many of the dwarf galaxies and found that the velocities are higher than can be explained by the mass of the visible galaxies. Without the mass surrounding the part of the galaxy we see, the stars should fly out into intergalactic space. But they don't, so there must be more mass — dark matter — enveloping these galaxies and keeping the stars in their orbits.



UK Schmidt/Royal Observatory, Edinburgh

CLOAKED BY DUST, the dwarf irregular galaxy NGC 6822 vigorously forms stars. Studies of star birth may shed light on how Local Group dwarfs get the material to make new stars. The thick Milky Way in Sagittarius, visible as parallel streaks, hides most of the light from this galaxy.



UK Schmidt/Royal Observatory, Edinburgh

THE DISTANT DWARF GALAXY DDO 210 is a probable member of the Local Group. Astronomers need more accurate measurements of its motion to confirm membership.

UK Schmidt/Royal Observatory, Edinburgh

THE SCULPTOR DWARF, an elliptical, contains orphan stars that have escaped other galaxies only to be captured by its gravity.

The question of dark matter in dwarf galaxies is hot because it may answer one of the big questions about the universe: How much mass does it hold? If as much as 98 percent of the mass in the universe exists in the form of dark matter (as many astronomers currently think) then the universe may have enough mass to ultimately stop expanding and fall back on itself in a Big Crunch. If dark matter is rarer than that, then the universe will expand forever. The Local Group dwarfs will help us measure how much exists in the universe. We can assume that other dwarf galaxies are pretty much like those in the Local Group and can ultimately estimate the total amount of matter in the universe.

Not all dark matter studies focus on such a big scale. Studying dark matter in the dwarfs lets us observe individual stars that belong to them. Curiously, some stars seem to be able to escape the gravitational grip of dark matter, at least briefly. Michael Irwin of Cambridge University has studied the structure of a number of dwarf ellipticals and found stars in odd orbits. Stars in such galaxies normally fit the King law, which describes how stars orbit a galaxy's center of mass. The law says that most of the stars follow radial orbits reasonably close to a galaxy's center. But some stars appear to lie beyond the tidal limits of the galaxy — that is, they have passed outside the gravitational lock of the galaxy's mass. Perhaps they were tugged out by the tidal effects of a nearby galaxy. Some such orphan stars may oscillate from galaxy to galaxy over incredibly long periods of time. The idea that stars escape their birth galaxy seems perfectly sensible. If another galaxy passes nearby, it's going to pull some stars out.

When we have a good feeling for the total dark matter in our Local Group, we'll be able to extrapolate that number out into deep space — into groups of galaxies, clusters, and superclusters, to the edge of the universe. The result will be enormously important: an estimate of the total dark matter in the universe and the knowledge of what will ultimately happen to the universe. It's ironic that such big questions may be answered by such little galaxies.

Cerro Tololo Interamerican Observatory

SEXTANS A is a dwarf elliptical that contains mostly old stars. When astronomers discovered a group of young ones, they began to ask what causes bursts of star formation in dwarf elliptical galaxies.

Pop Go the Starbursts

The most stunning revelation from the dwarfs may upset a longstanding belief within galactic astronomy. For 40 years, ever since Walter Baade discovered the nature of stellar populations, astronomers have believed that elliptical galaxies produce just one generation of stars and then sit around quietly for billions of years. To everyone's surprise, new research shows that many of the dwarf ellipticals have undergone at least two bursts of star formation.

This is the most exciting of recent discoveries about the Local Group dwarfs. Why did a certain galaxy suddenly burst into starmaking after doing nothing for billions of years? And why, having then made stars for a couple million years, did it shut down again?

The starbursts take place on a smaller scale than the starbursts in big, active galaxies. Astronomers have known about the latter type for years. Rather than lighting up the cosmos around them the way giant active galaxies do, dwarf ellipticals produce starbursts that change them temporarily into dwarf irregulars, making them briefly brighter and bluer.

The Fornax dwarf galaxy illustrates the riddle of the starbursts. Although most of the stars in the Fornax dwarf formed about 15 billion years ago, about 20 percent of the galaxy's stars appear to be only three billion years old. What could have caused stars to form in this galaxy after 12 billion years of sterility? No great supply of gas and dust, the stuff of which stars are made, exists in the galaxy. What triggered the starburst? What caused it to stop? The Fornax dwarf is not alone: Another Local Group dwarf, the Carina dwarf, has stars with ages similar to those of the Fornax dwarf, but a much larger percentage of Carina's stars formed more recently than those in Fornax.

Monica Tosi and her collaborators at the Osservatorio Astronomico di Bologna in Italy are studying the histories of starbursts in irregular dwarfs. By precisely measuring the brightness and color of stars in many of the Local Group dwarf irregulars, Tosi has assembled state-of-the-art color-magnitude diagrams to study the types of stars in the galaxies. These diagrams plot the color-brightness relationships of individual stars. By comparing her diagrams to models of how stars evolve, Tosi is starting to classify periods of high and low star formation for individual galaxies. During certain periods, the rates of star formation are much higher than in others.

Astronomers don't yet know why these starbursts occur. They speculate that active periods of star birth are triggered by the tidal effects of encounters with other galaxies, something we know has happened in the Magellanic clouds. Whatever the cause, a definitive answer may not be far off because astronomers are collecting data rapidly. For now, the starburst activity explains a number of observations of ellipticals outside the Local Group that until now didn't make sense. For example, long ago astronomers observed strong hydrogen absorption lines in the spectra of ellipticals, which indicated the presence of young stars. These couldn't be explained easily if the galaxies had only one era of star formation. Now the observations make sense: Probably many distant ellipticals have gone through recent periods of increased star birth.

Dwarfs Are Giants

If research of the past couple of years indicates the future, then dwarf galaxies will be the giants of future galaxy studies. From studying their motions we'll unravel the complex history of the Local Group and peer ahead to the demise of some of our neighbor galaxies. From studying the amount of dark matter they contain, we'll infer the nature of dark matter and perhaps the ultimate fate of the universe. Also, we'll understand the way galaxies make stars and the mechanisms that make some galaxies rich breeding grounds and others sterile. With the Local Group dwarfs as our example, we'll begin to see galaxies in remote parts of the universe more clearly.

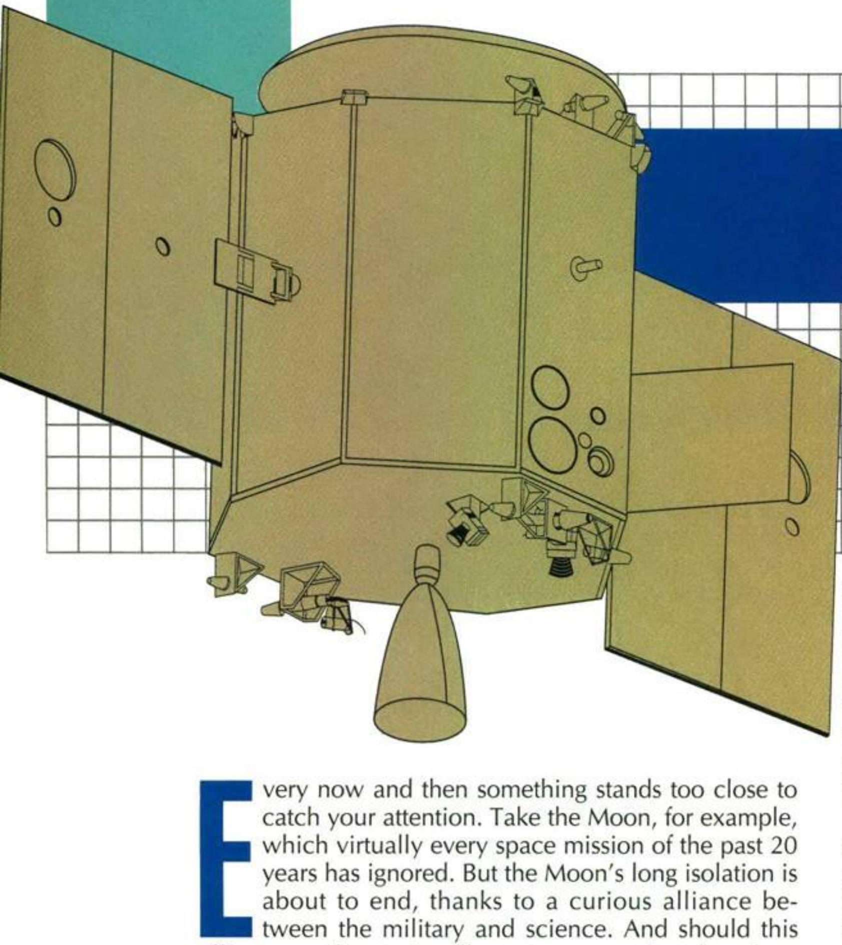
We learn a lot by studying a family. And in the case of our galactic family, as in many families on Earth, it's the little ones that reveal the family secrets. □

Paul Hodge of the University of Washington specializes in Local Group research and serves as editor of The Astronomical Journal. *Margaret Moulden, who prepared the color photographs, studies at Columbia University.*

THE MOON-MINER'S DAUGHTER

As star warriors and planetary scientists make a marriage of convenience, their offspring will be the first U. S. mission to the Moon since 1972.

by Robert Burnham



CLEMENTINE, THE FIRST U. S. MISSION TO THE MOON since the 1970s, will be an unusual joint venture of the Defense Department and NASA. If it succeeds, other hybrid missions may follow.

A CRAZY QUILT OF MINERAL TYPES, the Moon was cursorily surveyed by Galileo during two flybys past Earth. Scientists expect Clementine will greatly improve on Galileo's results in resolution and global coverage.

Every now and then something stands too close to catch your attention. Take the Moon, for example, which virtually every space mission of the past 20 years has ignored. But the Moon's long isolation is about to end, thanks to a curious alliance between the military and science. And should this alliance work out, it will create a precedent for others like it in the years to come. It's a prospect that worries some scientists while delighting others.

Odd Couple?

If all goes according to plan, on January 25, 1994, a Titan IIG rocket (recycled after spending 25 years in an Arkansas ICBM silo) will blast off from Vandenberg Air Force Base on the California coast. It will carry an unusual payload: Clementine, a spacecraft built by the Ballistic Missile Defense Organization (BMDO, formerly the Strategic Defense Initiative, or "Star Wars") to test advanced missile-detection sensors and other hardware. These state-of-the-art devices, and the powerful onboard computers running them, make Clementine a highly capable spacecraft.

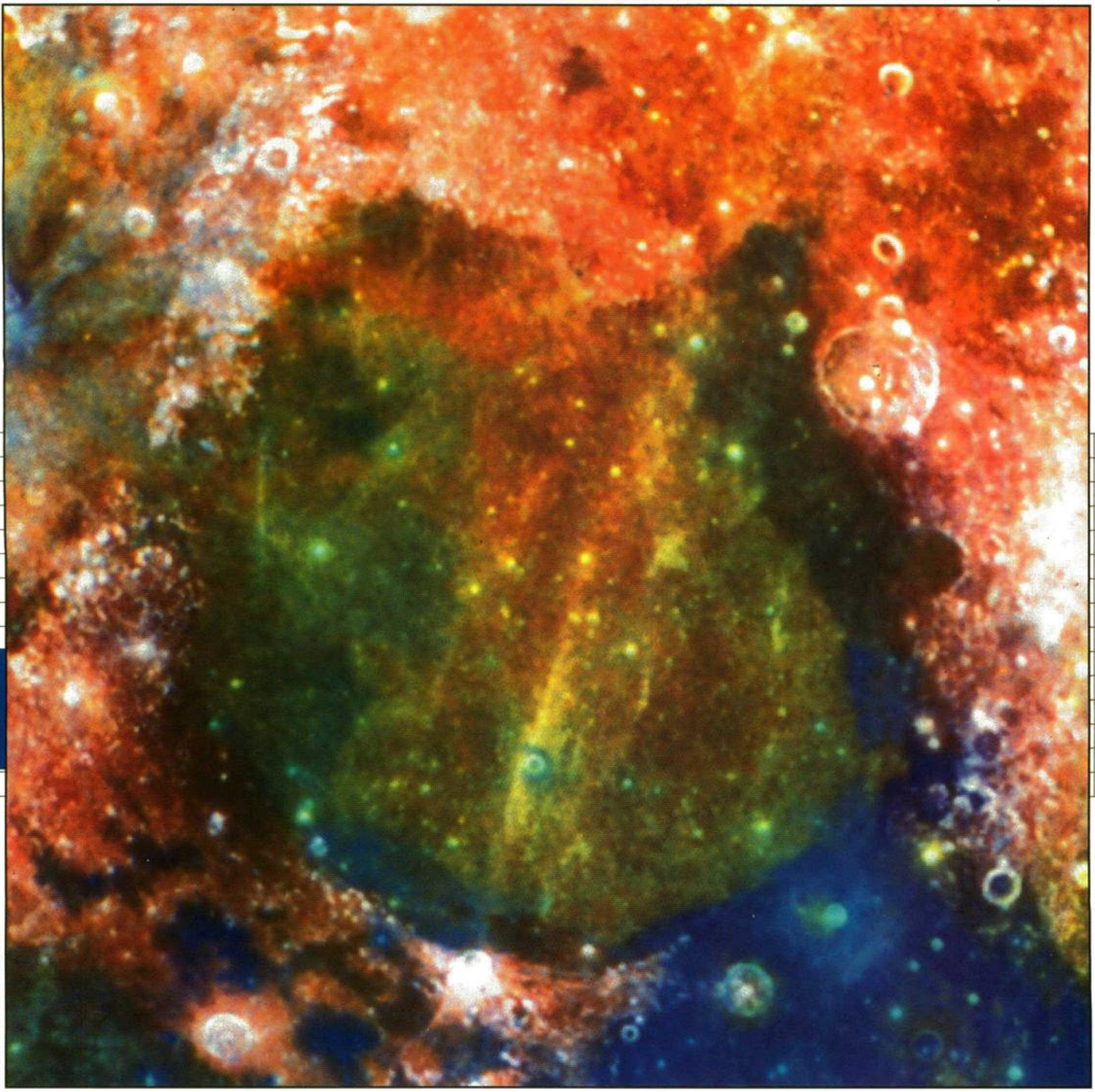
What makes Clementine really unusual, however, is the craft's *other* mission: mapping the Moon's surface rocks and studying an asteroid, 1620 Geographos. Never before has the American military collaborated with scientists on a test like this. The Clementine project began in 1991 when the Defense Department joined with NASA to investigate whether useful science could come from extended space tests of military surveillance hardware.

"NASA's approach was one of 'Let's see what science we can get out of this.' For the Defense Department, it was a recognition that they are working in a new environment," says Carlé Pieters of Brown University, one of the project scientists.

From the military's point of view, flying instruments to an asteroid allows it to comply with the Antiballistic Missile Treaty (which forbids tests on manmade objects) and will give hardware a thorough workout on a long-duration mission. From NASA's standpoint, the project offered an unexpected chance to send multiwavelength cameras to the Moon and an Earth-crossing asteroid.

Besides a free ride into space, NASA should benefit from the project's technology transfer: miniaturized cameras, star trackers, a powerful battery, and navigation instruments. These may aid the development of NASA's own line of small planetary missions, called Discovery, and its MESUR program to survey the Martian environment (see "Cheap Shots," August 1993).

The mission's name is a whimsical reference to the old song about the Gold Rush miner's daughter. But it's



Alfred McEwen/USGS Flagstaff

not inappropriate: Once Clementine's mission is over, it will indeed be "lost and gone forever" because there are no plans to send it to any other targets.

Despite the joint nature of the project, it's important to keep in mind that Clementine is a military test flight with a science byproduct. According to one scientist working on the mission, however, the military "bent over backward" to accommodate the scientific goals. For example, all but one of the camera filters, important for distinguishing surface minerals, were chosen by the scientists. And at the scientists' request, the power of the laser-ranging instrument was strengthened to the point where it may yield a global altitude map of the Moon, a bonus unanticipated at the project's inception.

The mission's military origins have provoked some unease among scientists, among them Clark Chapman of Tucson's Planetary Science Institute.

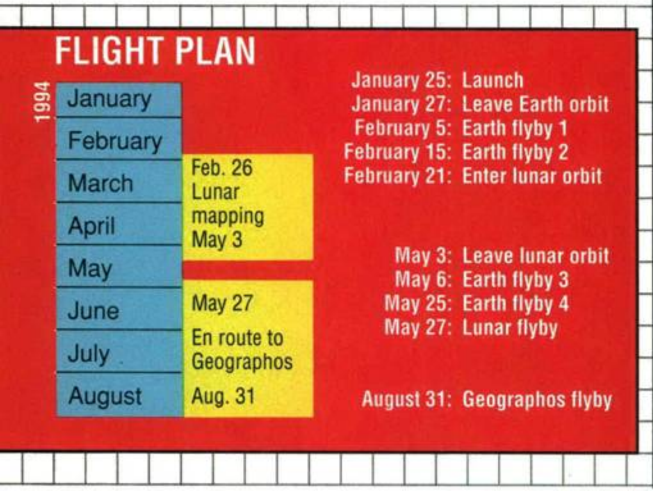
"My first reaction to Clementine," he says, "is that someone is finally doing something about asteroids — which NASA hasn't. And I like the 'can do' spirit of the BMDO people who have gotten this thing started in record time.

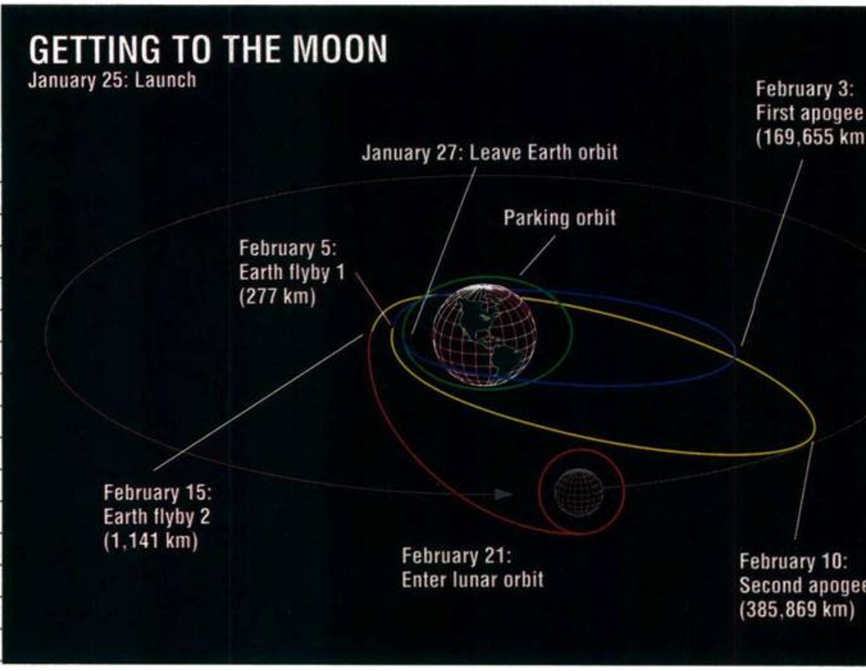
"But the collaboration worries me because these instruments are less capable than they would have been if scientists had been involved from the beginning. Clementine isn't, therefore, a replacement for asteroid missions that need doing, and it shouldn't be a model for how to do future planetary missions."

Most planetary scientists agree that getting fresh lunar and asteroid data is well worth the joint effort. After all, many note, the Defense Department was going to fly the instruments anyway. Why pass up a chance to try for scientific results with them?

"For 20 years NASA talked and talked about mapping the Moon globally," says Paul Spudis of Houston's Lunar and Planetary Institute, a member of the science team. "We've seen one paper project after another come and go. This time, it's finally going to happen."

"I'm tremendously excited," says Eugene Shoemaker, recently retired from the U. S. Geological Survey and leader of Clementine's science team. He is delighted by a chance to send instruments to the Moon, but also acknowledges that Clementine will depend on unproven hardware.


FLIGHT PLAN
1994
January
February
March
April
May
June
July
August
Feb. 26
Lunar mapping
May 3
May 27
En route to Geographos
Aug. 31
January 25: Launch
January 27: Leave Earth orbit
February 5: Earth flyby 1
February 15: Earth flyby 2
February 21: Enter lunar orbit
May 3: Leave lunar orbit
May 6: Earth flyby 3
May 25: Earth flyby 4
May 27: Lunar flyby
August 31: Geographos flyby


GETTING TO THE MOON
January 25: Launch
February 3:
First apogee
(169,655 km
January 27: Leave Earth orbit
Parking orbit
February 5:
Earth flyby 1
(277 km)
February 15:
Earth flyby 2
(1,141 km)
February 21:
Enter lunar orbit
February 10:
Second apoge
(385,869 km)

"Clementine's a risky mission. But in the unmanned flight business, you have to learn to relax the reliability requirements and accept some failures.

"Clementine's low-cost approach is the only way for the future. If every mission costs $1 billion, there won't *be* any. I think success with Clementine will shake the system up. The example will force NASA to do truly innovative missions."

Can Swords Make Plowshares?

Given that Clementine is a test of missile-detection systems, it's no surprise that the Defense Department is picking up the tab for the flight. Two defense agencies are involved: The Naval Research Laboratory built the spacecraft and will fly it, while the Lawrence Livermore National Laboratory will conduct the missile test experiments. From the civilian side, NASA's Goddard Space Flight Center designed the spacecraft's trajectory, and the Jet Propulsion Laboratory will provide support in optical navigation and in tracking Geographos. NASA's Deep Space Network will help the Defense Department track the craft and handle communications.

Clementine's instrument package (developed by the BMDO) is impressive. An ultraviolet/visible CCD camera will map the entire Moon at resolutions of 125 to 325 meters (depending on where Clementine is in orbit). At its planned 100-kilometer closest approach to Geographos, this instrument's highest resolution will be 25 m. The near-infrared camera has a lunar resolution varying between 200 and 500 m, while at Geographos the best resolution will be 40 m. A long-wavelength infrared camera will be used primarily for thermal sensing. A LIDAR (laser imaging and ranging) device will measure the distance between the target and the spacecraft to 40 m, while a very high resolution LIDAR CCD camera will image small portions of the Moon at resolutions of 10 to 30 m and Geographos at 5 m. Last, a charged-particle detector will measure ions and electrons in the spacecraft's environment during the flight.

While choosing as a target an asteroid whose orbit crosses that of Earth might seem like a Flash Gordon trick, it isn't so farfetched. Earth-crossers such as the Apollo and Amor groups to which Geographos belongs pose a real threat. Sixty-five million years ago, a comet or asteroid about 15 km in diameter plowed into the Yucatán region and created a global environmental catastrophe. (Impacts are suspected in other mass extinctions as well.) Some new studies indicate that many asteroids will break up or explode in Earth's atmosphere before hitting the ground. But it's also clear that if a Tunguska-like body (see "Death from the Sky," December 1993 issue) fell on a major city today, the cost would be, well, astronomical.

In 1991 NASA studied the likelihood of large asteroid impacts on Earth. The study also looked at ways of preventing such catastrophes. Called Spaceguard, the resulting plan envisioned building telescopes in both hemispheres to find every asteroid larger than 1 km in diameter. When found, these objects would have their orbits plotted and checked to see if any were on a collision course with Earth.

If any asteroid did pose a danger, possible ways of dealing with it might include sending missiles to intercept it and change its speed a little with nuclear explosions. If the asteroid were found an orbital revolution or two before impact, a small change in velocity could cause it to miss Earth entirely. Clementine's ability to navigate to a rock in space could play a useful role in this mission, if necessary.

Clementine may have other lessons for NASA, too — in mission planning, for example: The project went together very fast.

"About two years from an idea on the back of a cocktail napkin to returned data," says Spudis. "That's a pace that NASA used to have back around 1962.

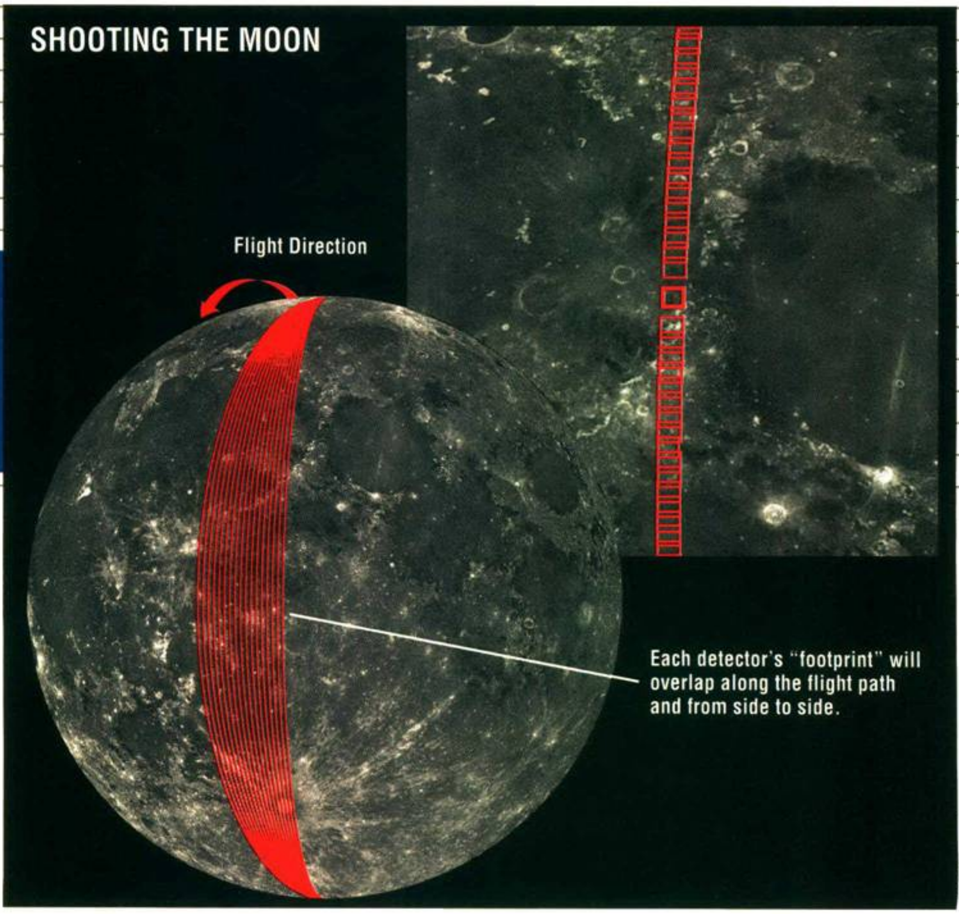
"This is a real test of NASA's new theme of faster, cheaper, better. Clementine is a bellwether — if we can pull this off, it'll tell NASA something."

Second, Clementine will cost just $75 million, cheap by space-probe standards, especially considering this covers both the primary craft and its backup. These figures may be a little misleading because Clementine builds on previously developed technology. But it still beats NASA's Discovery missions, which have ceilings of $150 million and are expected to take three years from start to finish, not two.

ORBITAL ROLLERCOASTER? **Clementine will use a low-energy, roundabout way of going to the Moon. Such flight paths lessen the demand for fuel and thus keep spacecraft weights low.**

LIKE MAGELLAN AT VENUS, Clementine will wrap the Moon in a network of orbital tracks. Strange as it seems a quarter-century after Apollo, the Moon has never been surveyed globally.

SHOOTING THE MOON



Each detector's "footprint" will overlap along the flight path and from side to side.

Lick Observatory

What's New on the Moon?

To get Clementine to Geographos, mission planners will use the Moon and its gravity. Our satellite is handy, quick to get to, and as any planetary scientist will tell you, it hasn't gotten much attention in the past few decades.

But does the Moon need more looking at? Didn't the Apollo astronauts bring back enough rocks to tell us everything there is to know about the Moon?

Indeed, Apollo's rock samples (and two cores from unmanned Russian probes) have told a great deal about the Moon. But they left unanswered some pretty major questions. It's easy to see why. Apollo visited only six sites on the nearside chosen mainly to be safe and easy to get to. All of them lay fairly near the equator, and most were in the maria, the plains of lava that oozed out late in lunar geological history. The Apollo sites therefore offer only a limited view of the Moon.

In addition, Apollo just scratched the surface — literally. Most rocks the astronauts picked up came from the dusty surface. The longest Apollo core sample reached into the Moon only 3 m and the number of cores is a handful. Judged by what was known before, Apollo was a tremendous triumph. Yet judged by standards of terrestrial fieldwork, Apollo could certainly be improved on.

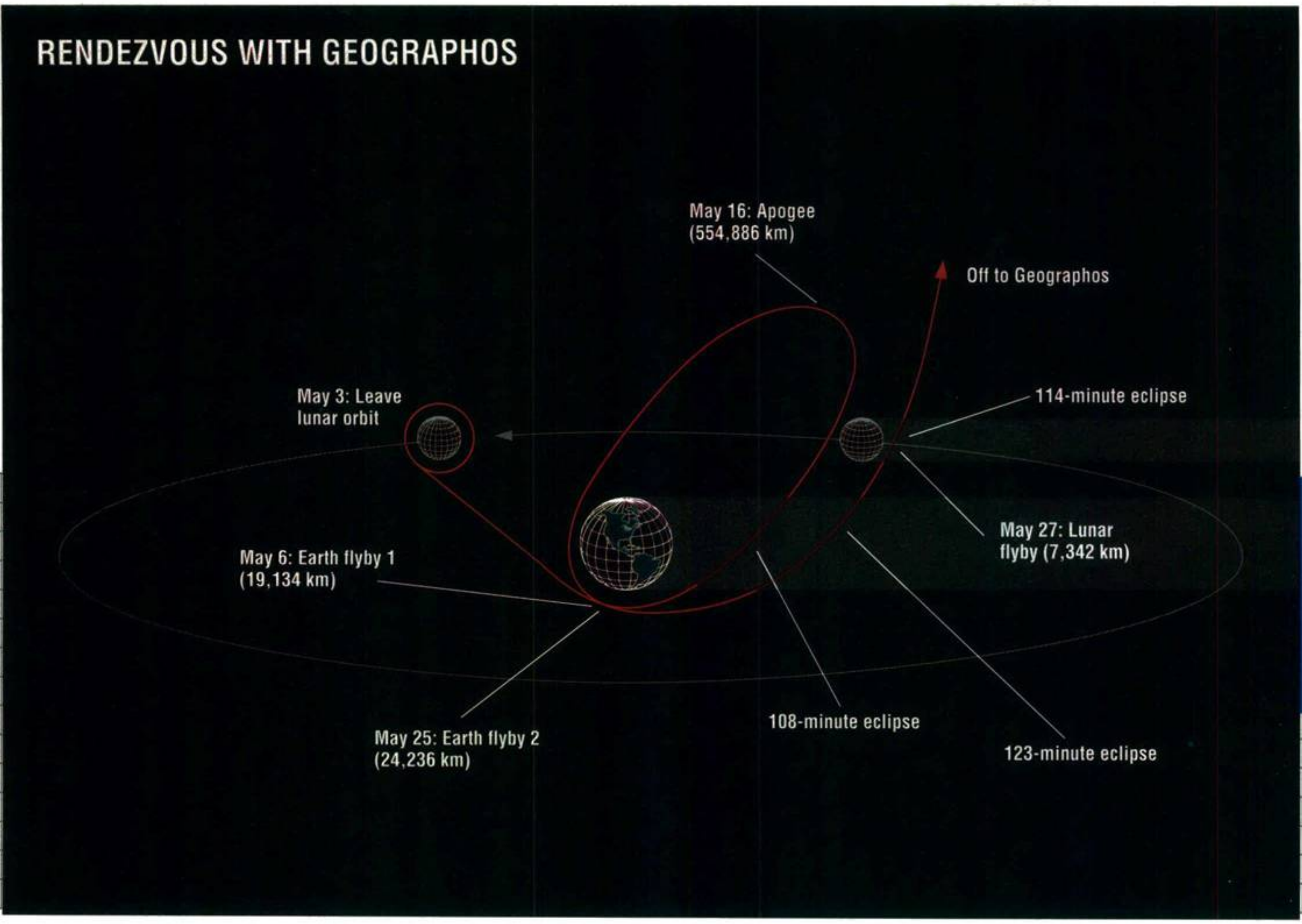
But short of actually landing on the Moon again, how can lunar scientists probe beneath the Moon's surface and sample it? The answer lies in a riddle: When is a meteorite not a meteorite? When it's a geological hammer.

"Craters are natural drill holes into the lunar crust," says Spudis. The violence of a meteorite impact blows a wide, deep hole in the lunar surface and sprays buried rocks all around. The bigger the meteorite, the bigger the crater and the deeper it reaches. Impacts open up rock layers you can't see. By using crater ejecta as core samples, scientists can study the rocks far beneath the Moon's face and begin to sketch-in hidden details of its history.

Every telescope owner knows, however, that the Moon basically comes in a few shades of gray. Telling one kind of lunar rock from another isn't easy — to the human eye. But other "eyes" can see more: for example, the multiwavelength sensors on the Galileo spacecraft briefly imaged parts of the Moon during two quick flybys in 1990 and 1992. Processed into false colors to highlight differences, those images show a startling variety in the maria and highlands (see page 35).

Silicate rocks, common on the Moon (and asteroids),

RENDEZVOUS WITH GEOGRAPHOS



are easily distinguished by type when seen at infrared wavelengths. One of Clementine's tasks is to make the first global multispectral map of the Moon. Scientists will then use the "ground truth" derived from Apollo samples to calibrate these data and extend the multispectral analysis into unexplored regions.

"The Moon is a good target for us," says Pieters. "We have samples of some of its soils, and we can use these to test what Clementine measures."

Related to multispectral mapping will be thermal sensing — detecting where the Moon is anomalously warm or cool. Such data can indicate places where the dust coats the rocks thinly or thickly and also pinpoint fresh outcrops by their coarse, broken rock.

Additionally, Clementine will map accurately the Moon's shape and topography, another task left undone since Apollo days. (Believe it or not, the unseen surface of Venus is known to far better precision!) Clementine will fire laser pulses downward about every kilometer along its orbital track, measuring the height of the ground to about 40 m between latitudes 30° north and south. Orbit by orbit, Clementine will slowly weave a grid of measured altitudes over the Moon.

Minor Planets, Major Mysteries

Busy as Clementine will be at the Moon, this is still only half the mission. The second part focuses on the minor planet Geographos, one of the Apollo group of asteroids that cross Earth's orbit around the Sun. When Clementine meets it in August 1994, Geographos will lie at a distance of 8.5 million km from Earth.

Because Geographos shows a 2-magnitude variation in brightness every 5.2 hours, astronomers believe it is a tumbling chunk of irregular rock measuring roughly 1.5 km by 4 km. Geographos' orbit carries it from 0.84 astronomical unit (near Venus' orbit) out to 1.65 AU (beyond Mars) over a 1.4-year period. This year's close approach to Earth is fairly rare: Most years Geographos passes many more millions of kilometers away.

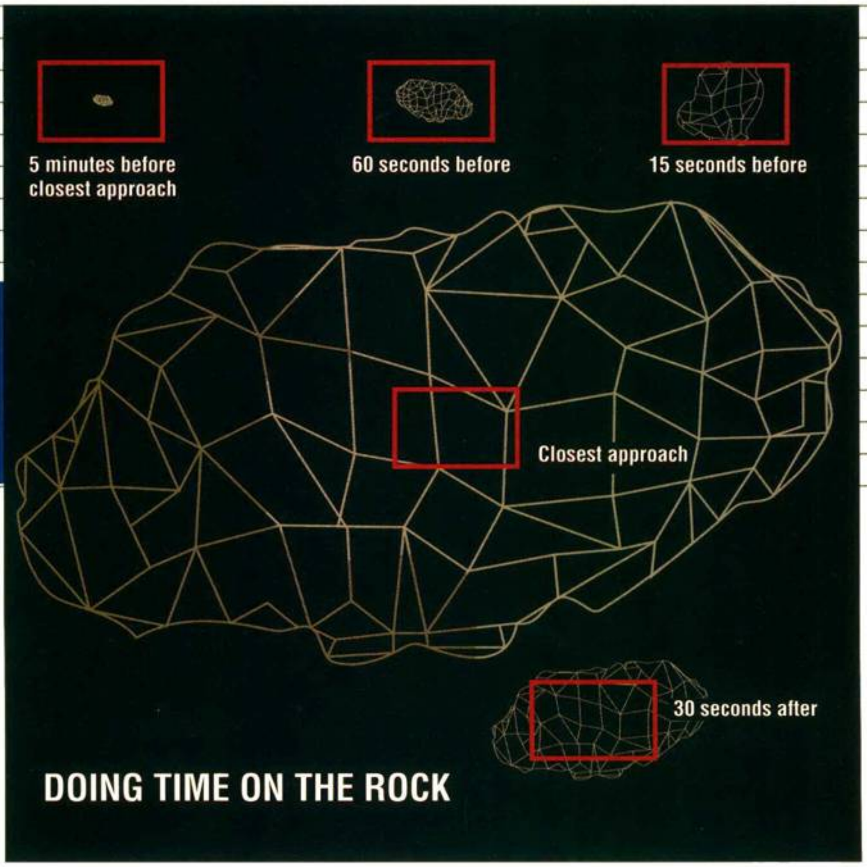
As the name "asteroid" suggests, Geographos looks starlike in a telescope. (Seen from Earth, it will be about 10th magnitude at the time of encounter and should be visible in 4-inch or larger backyard telescopes.) Everything astronomers know about Geographos has come from analyzing its reflected sunlight. Spectroscopy shows Geographos is the commonest kind of Earth-crossing asteroid. Its surface is probably dusty and cratered, while the size and number of craters can show how many years have passed since Geographos was last part of some larger body.

"This will be our first close-up look at an Earth-crosser," says Gene Shoemaker. "Geographos has the greatest change in brightness of any asteroid we've seen; that means it's shape is unusual — highly elongated. I've a hunch it's a couple of pieces stuck together, but it could just be a big shard of rock.

"Another interesting thing about Geographos is that objects in Earth-crossing orbits aren't stable over the age of the solar system. Some event delivered Geographos into its current orbit; when we see how old its surface is, we'll be able to date when that happened.

"Also, while Geographos isn't a danger to Earth for the foreseeable future, if it *is* a loose collection of pieces, that would make any attempt to modify its orbit kind of difficult, to say the least."

Clementine's instrument package will perform the same studies at Geographos as at the Moon, but the time available is much shorter because the encounter is a high-speed flyby. For example, Geographos will overflow the frame of the highest resolution imager for only about two minutes in all: from 60 seconds before closest approach to 60 seconds after. Nonetheless, mission scientists hope to get at least 2,000 images of the asteroid, which will be stored in the craft's 1.6-gigabyte solid-state memory for playback after the flyby.



GETTING TO GEOGRAPHOS ON THE CHEAP calls for clever maneuvers like those that sent Clementine to the Moon. During the three eclipses, the ion detectors will collect data on the solar wind and its interaction with the Earth and Moon.

A FAST LOOK IS ALL that Clementine will get at Geographos. The highest resolution images will be squeezed into a few seconds before and after closest approach.

One big question regarding asteroids is that with roughly 17,000 objects known (out of a population that could number in the billions), just how many do we have to examine to get an accurate picture of their collective history? Their assorted geologies? Clementine won't provide all the answers, but it will add appreciably to the store of knowledge — and at this stage of asteroid science, every new finding counts as a major advance.

Filing the Flight Plan

Clementine's path out to Geographos will be anything but straightforward. Following launch, Clementine will spend a couple of days in Earth orbit. Then it will fire its engine and coast out to 170,000 km before falling back toward Earth in the first of two "phasing orbits." Then it flies by Earth at 277 km altitude. Pumped up by Earth's gravity, Clementine next sails out 386,000 km for its second apogee — and falls back once again. Its second perigee is 1,141 km high and provides enough energy for the craft to reach the Moon on February 21, 1994.

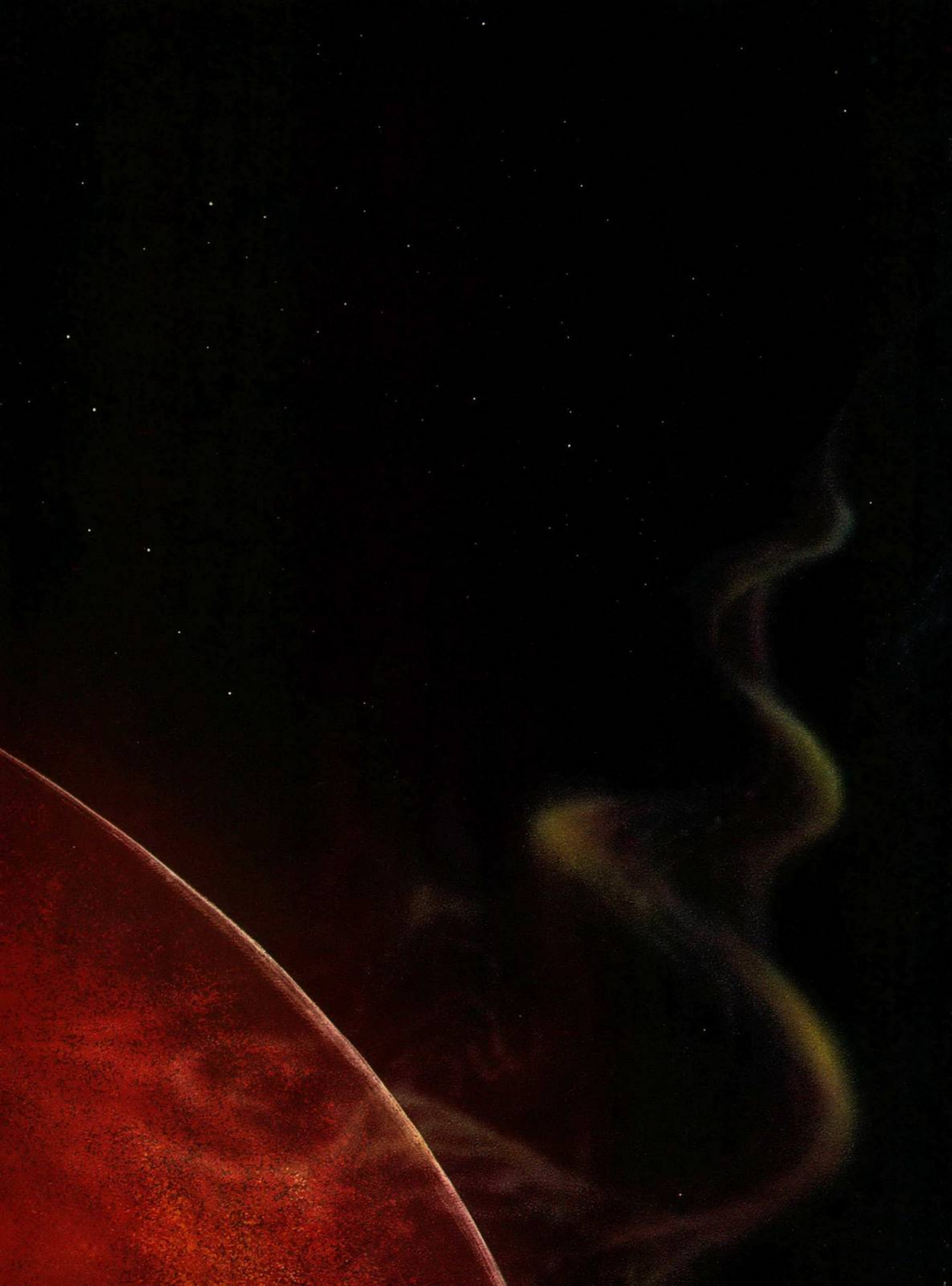
Clementine will enter an eccentric polar orbit around the Moon with a perilune (closest approach) of 425 km and an apolune of about 8,300 km. Over the following two months, it will map the Moon pole to pole. First the southern lunar hemisphere will be scrutinized at highest resolution, then the northern. On May 3, Clementine will leave lunar orbit, perform two more phasing orbits around Earth, and head out to Geographos (see opposite). On August 31, 1994, Clementine will zip past Geographos at 10.7 km/second.

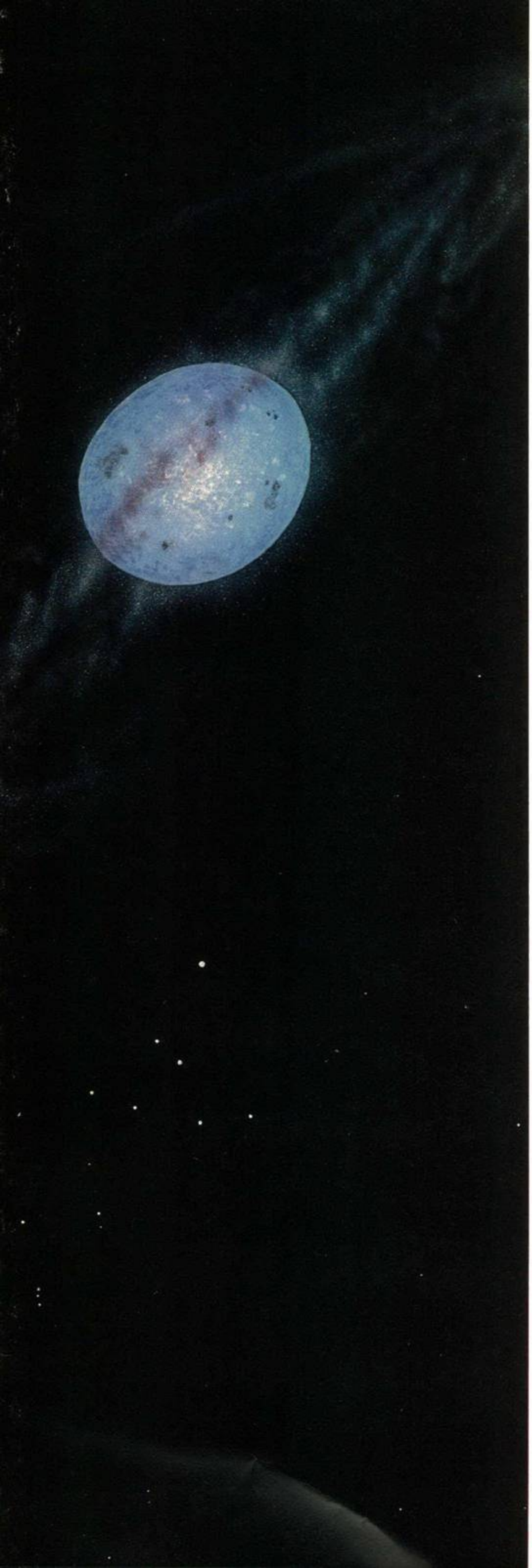
Approaching from the asteroid's night side about 40° away from a line directly toward the Sun, Clementine will aim to go within 100 km of Geographos. As it passes, the spacecraft will turn and look back to view the sunlit side of the asteroid. During the encounter, the craft will take images at several frames per second, which should make an exciting movie when spliced together. Then, after the data have been sent to Earth, the craft's fuel will be gone and its mission will be over.

"I'm really looking forward to data from Clementine," says Clark Chapman. "And I hope it whets everyone's appetite for studying asteroids even more in the future — with a full complement of the necessary instruments."

With its joint military/civilian origins, Clementine marks a new way of doing business for NASA and planetary science in general. It's also a product of our times as the Cold War military explores a new openness.

"I think planetary science should be pursued in the U. S. chiefly by a civilian space agency," remarks Chapman. "But NASA needs a thorough overhaul and shake-up. If it can capture some of BMDO's enthusiasm, that would be great. But NASA also needs to retain its traditional goals of excellence and cost-effectiveness as exemplified by the Voyagers." ☐





Michael Carroll

COSMIC CHAMELEON

THE SUPERNOVA IN M81

An unexpected change in this supernova's spectrum has forced astronomers to rethink their ideas about how massive stars explode.

by Laurence A. Marschall

"A supernova has been discovered in M81 by some amateurs in Madrid. It will be one of the brightest we've had in a long time. Happy observing!" Sent to astronomers around the world by electronic mail on the morning of March 30, 1993, this message heralded the arrival of a new superstar, the brightest celestial explosion since 1987's supernova in the Large Magellanic Cloud.

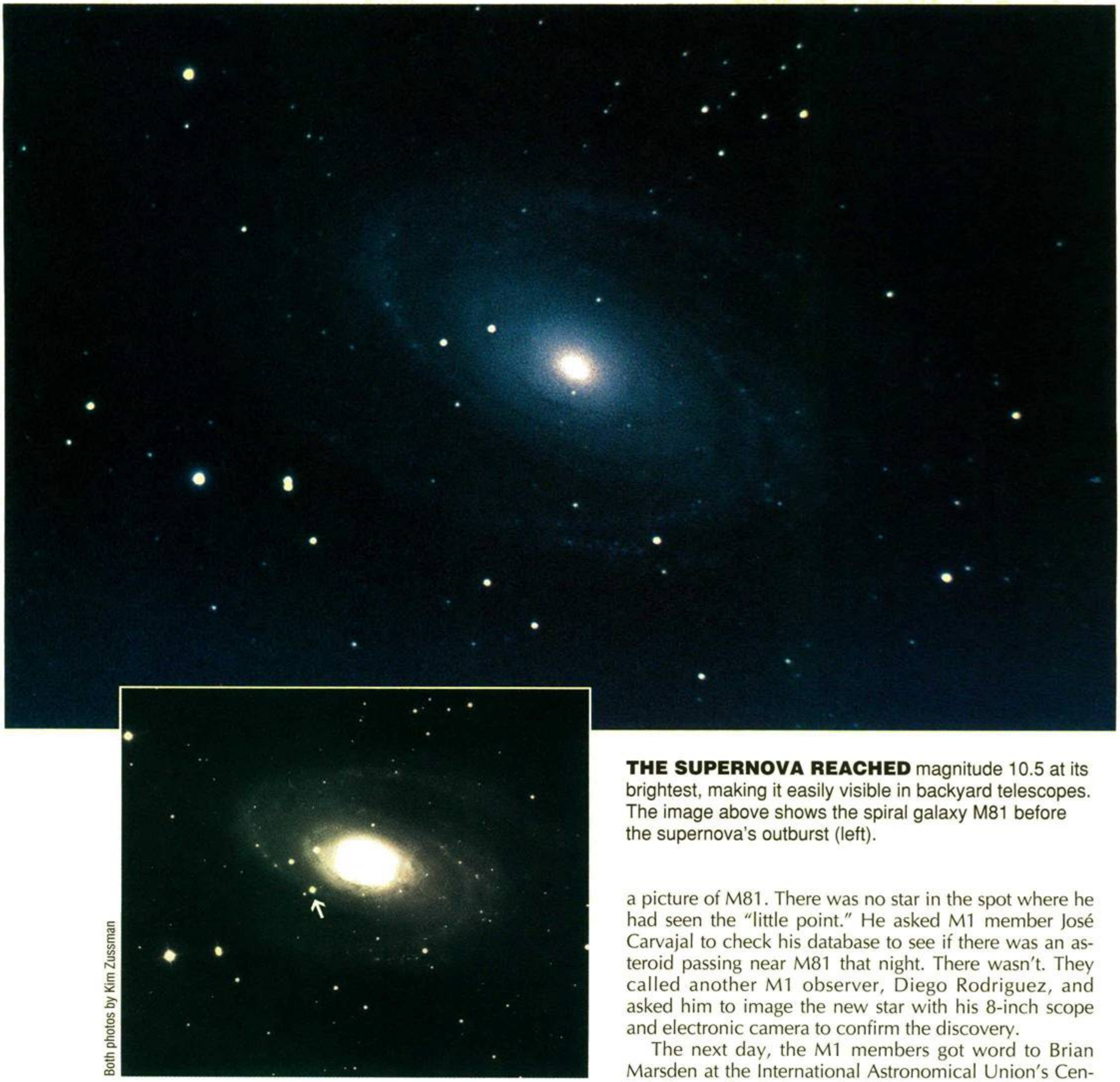
Astronomers found that, like the 1987 supernova, the supernova in M81 contradicted their ideas about which massive stars will explode as supernovae. They also found that this supernova didn't fit into their scheme for classifying the progenitor star's spectrum. Only the second supernova for which astronomers have identified the progenitor star, this stellar outburst taught them a lot about how massive stars end their lives.

A Backyard Discovery

It was no surprise that amateurs discovered supernova 1993J, the tenth one found that year. The world's few thousand professional astronomers don't have enough telescope time to search millions of galaxies for a supernova outburst. So they welcome all the help they can get from backyard astronomers.

In 1989, a half dozen members of the Madrid Astronomical Association formed a supernova search team called the M1 group. On clear nights the members of the group scan selected galaxies, hunting for something that wasn't there when they looked last. If a star seems out of place, they check their charts. Invariably the new light turns out to be a known star, a passing satellite, or an asteroid scooting around the solar system.

SUPERNOVA 1993J'S UNIQUE CHARACTER resulted from the loss of two-thirds of the progenitor star's mass. The reddish yellow supergiant ejected some of this mass and a companion star may have stripped the rest.



THE SUPERNOVA REACHED magnitude 10.5 at its brightest, making it easily visible in backyard telescopes. The image above shows the spiral galaxy M81 before the supernova's outburst (left).

Both photos by Kim Zussman

In 1993 they got lucky. At about 9 p.m. on March 28, Francisco García Diaz, a charter M1 member from Lugo, just outside Madrid, decided that the night was nearly perfect for observing. He pointed his 10-inch telescope at M82 in Ursa Major, just to check the clarity of the sky. Then he moved the telescope a bit southward, bringing into view the cottony spiral of M81, a magnificent galaxy that is a favorite of observers.

Right away, García noticed a 14th-magnitude star that hadn't been there on earlier nights. "What is that little point?" He thought — not really expecting success to come so easily. He got so excited, he recalls, that he slipped from the stool he was standing on and wound up sitting on the floor.

Hurrying home, García checked his celestial atlas for a picture of M81. There was no star in the spot where he had seen the "little point." He asked M1 member José Carvajal to check his database to see if there was an asteroid passing near M81 that night. There wasn't. They called another M1 observer, Diego Rodriguez, and asked him to image the new star with his 8-inch scope and electronic camera to confirm the discovery.

The next day, the M1 members got word to Brian Marsden at the International Astronomical Union's Central Bureau for Astronomical Telegrams in Cambridge, Massachusetts. He sent the announcement of the supernova out over the electronic mail networks and telephone lines, allowing astronomers to gear up rapidly.

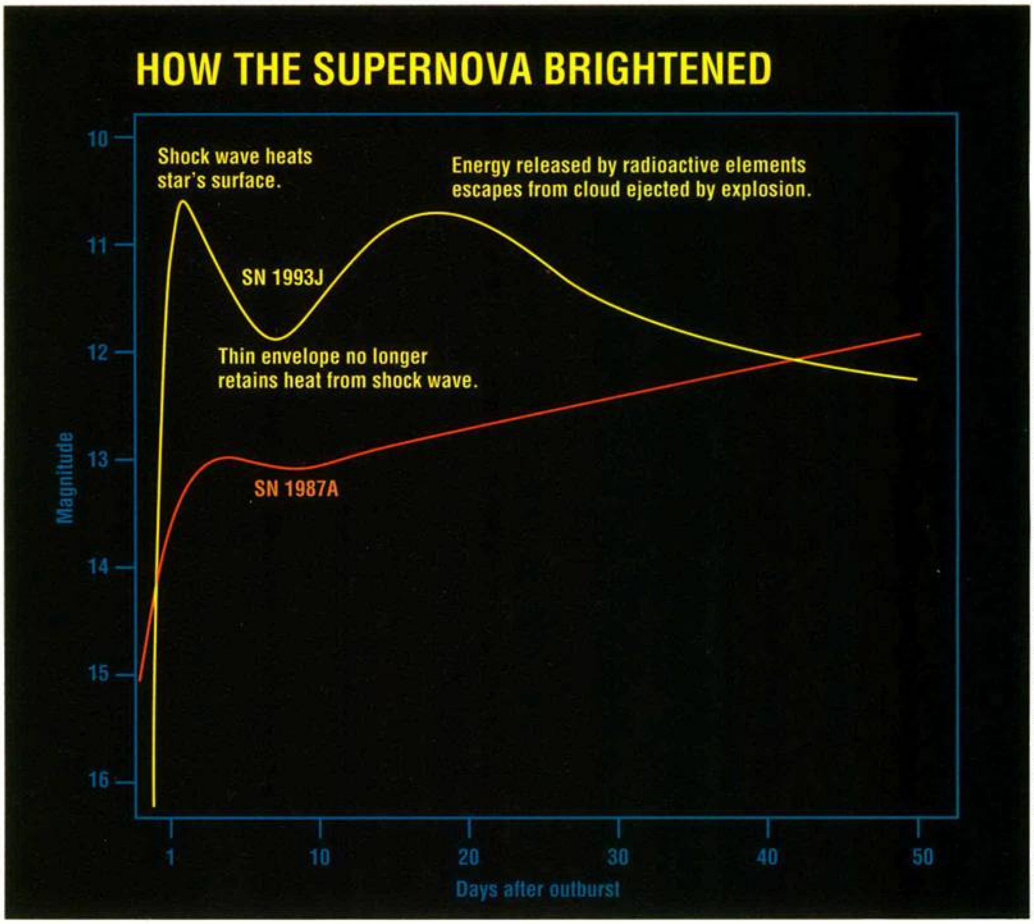
García and Rodriguez anxiously waited until dusk on March 29 to see if their "little point" was still there. They found it easily, the star having risen in brightness to 11th magnitude. The next day they learned that a group led by Alexei Filippenko, an astronomer at the University of California in Berkeley, had taken spectra of the object, confirming that it was indeed a supernova.

Unexpected Explosion

Supernova 1993J was a discovery of exceptional importance. Though it never rose brighter than about magnitude 10.5 (about 1,000 times fainter than SN 1987A at its maximum), it was the brightest supernova visible from the Northern Hemisphere since SN 1954A, which appeared in an irregular galaxy in Canes Venatici. Since SN 1993J was close to the north celestial pole, it was high in the sky for northern observers during most of the year, making it possible for them to monitor the supernova almost continuously.

SN 1993J was exceptionally bright because its parent galaxy, M81, is close, about 11 million light-years from our Milky Way Galaxy. The presence of a supernova in such a well-studied part of our neighborhood raised astronomers' hopes that they could identify its progenitor star. Only one supernova had a known progenitor — the blue supergiant called Sanduleak –69°202 that became SN 1987A — and astronomers were eager to discover another.

Soon after Marsden announced SN 1993J, astronomers examined images taken before the supernova's outburst and reported that a 21st-magnitude object lay at the site of the explosion. Greg Aldering and Roberta Humphreys of the University of Minnesota and Michael Richmond of Princeton University found that the object appeared to be a blend of at least two stars. From its apparent color, they identified the supernova progenitor as a reddish yellow supergiant, about 200 times the diameter of the Sun and slightly cooler. It was neither a blue supergiant, like the one that produced SN 1987A, nor a red supergiant, which classic theories of stellar aging predicted should become a supernova. Clearly SN 1993J had new lessons to teach us.



SN 1993J data from Brian P. Schmidt, Harvard-Smithsonian Center for Astrophysics, et al.

TWO PEAKS MADE SN 1993J different from other supernovae such as SN 1987A (shown relative to SN 1993J's absolute brightness).

Split Personality

The electronic superhighway, the worldwide network of computers called Internet, provided astronomers with an almost instantaneous link to pictures of the supernova, X-ray and radio data, and plots of the supernova's changing brightness called light curves. From the beginning, the supernova showed its unique character.

Though the light curve of SN 1993J appeared in many ways similar to those of other exploding stars, it also showed its own twists. The supernova seemed to reach a peak in brightness only a few days after García's discovery. (Researchers believe the explosion occurred on March 25, three days before its discovery.) For a week it dimmed steadily, leading astronomers to despair that it would disappear much faster than SN 1987A. Then, to everyone's delight, it brightened again, rising to a second maximum in mid-April. By the beginning of May it began to dim once again and it is now dimming at a steady rate, like the exponential decline of SN 1987A except considerably faster.

Researchers first thought this double peak was unusual and set SN 1993J apart from other supernovae. Now they're not so sure. Some astronomers believe that other supernovae may have produced double peaks but weren't discovered until after the first peak subsided.

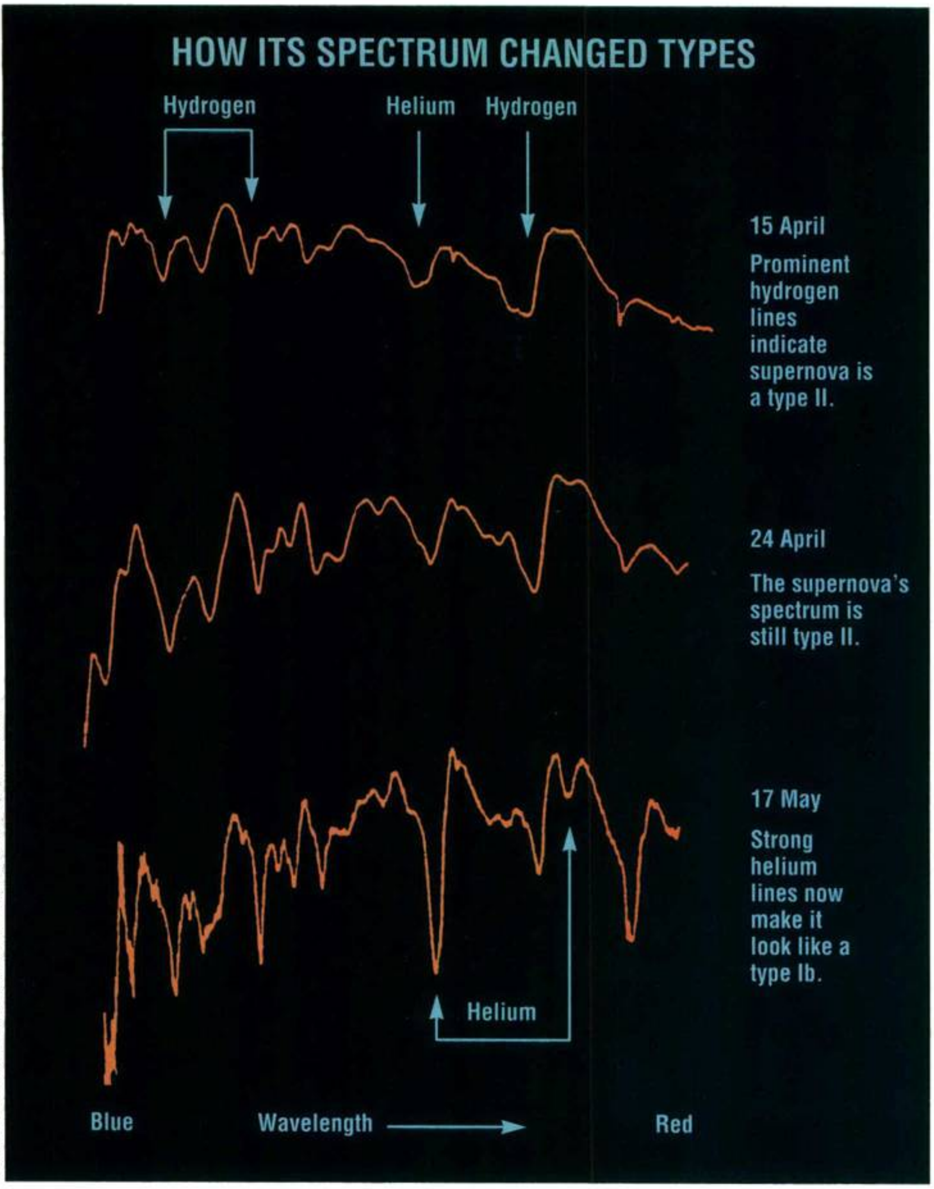
The light curve wasn't the only unusual characteristic of SN 1993J. When astronomers looked at the supernova's spectrum, they discovered that the supernova had a split personality: It couldn't decide what type it wanted to be.

Researchers classify supernovae by the lines in their spectra. Type I supernovae have no hydrogen lines while type II do. They further subdivide type I into type Ia (strong silicon lines) and type Ib (strong helium lines).

During the first few weeks after outburst, hydrogen lines dominated SN 1993J's spectrum, identifying it as a type II supernova. But by May the hydrogen lines had begun to fade and were replaced by lines of helium, making it look somewhat like a type Ib.

Astronomers believe that type II supernovae result from the collapse of stars with a mass 10 times greater than the Sun's. When the star's nuclear fuel becomes depleted, the interior collapses catastrophically to form a 10-kilometer-diameter neutron star. The outer layers bounce off the rigid core and balloon into space, demolishing the star in a final blaze of glory.

Type Ib supernovae also arise from massive stars, but ones that prior to the star's explosion lose their outer layers, which contain most of the star's hydrogen. So type II spectra have hydrogen lines and type Ib lack these lines. SN 1993J, though, was a combination of the



HOW ITS SPECTRUM CHANGED TYPES

15 April

Prominent hydrogen lines indicate supernova is a type II.

24 April

The supernova's spectrum is still type II.

17 May

Strong helium lines now make it look like a type Ib.

Brian P. Schmidt, Harvard-Smithsonian Center for Astrophysics, et al.

COSMIC CHAMELEON: The spectrum of supernova 1993J changed less than two months after the star exploded, ejecting its thin outer layer of hydrogen.

two types. The duality provides insight into the nature of the star that exploded to become SN 1993J.

Stripped Star

Suppose SN 1993J began life as a star with 15 to 20 times the mass of the Sun. As most massive stars do, it would have spent its last million years as a red supergiant. And then suppose that, in its last years, the star ejected about two-thirds of its mass — mostly hydrogen — leaving behind a heavy core, a shell of helium, and a thin outer skin containing less than half a solar mass of hydrogen. The star would appear hotter than a red supergiant, just like the reddish yellow supergiant reported to be the progenitor.

When such a "stripped" star exploded, it would exhibit behavior similar to that of SN 1993J. The hydrogen skin would show a hydrogen or type II spectrum at first but because the skin quickly dispersed, the helium shell would show the characteristics of type Ib supernovae in later spectra. The thinness of the hydrogen skin would also explain the unexpected initial dip in the light output.

Ordinary type II supernovae have thick skins containing many solar masses of hydrogen. This envelope stores the energy generated by the decay of radioactive nuclei and by the shock wave produced by the explosion. The envelope slowly releases the energy over several months.

But the thin envelope of a supernova like SN 1993J lets the energy of the shock pass through quickly, causing the shell to cool and dim rapidly as it expands into space. The second rise in brightness happens when energy released by the decay of radioactive nickel and cobalt finally filters out through the gas ejected by the explosion. The current decline in the supernova's brightness, which is more rapid than that observed for SN 1987A, could be due to the fact that SN 1993J threw off less material from its outer layers than SN 1987A. The thin cloud that resulted allows the energy from radioactivity to escape without being converted into visible light.

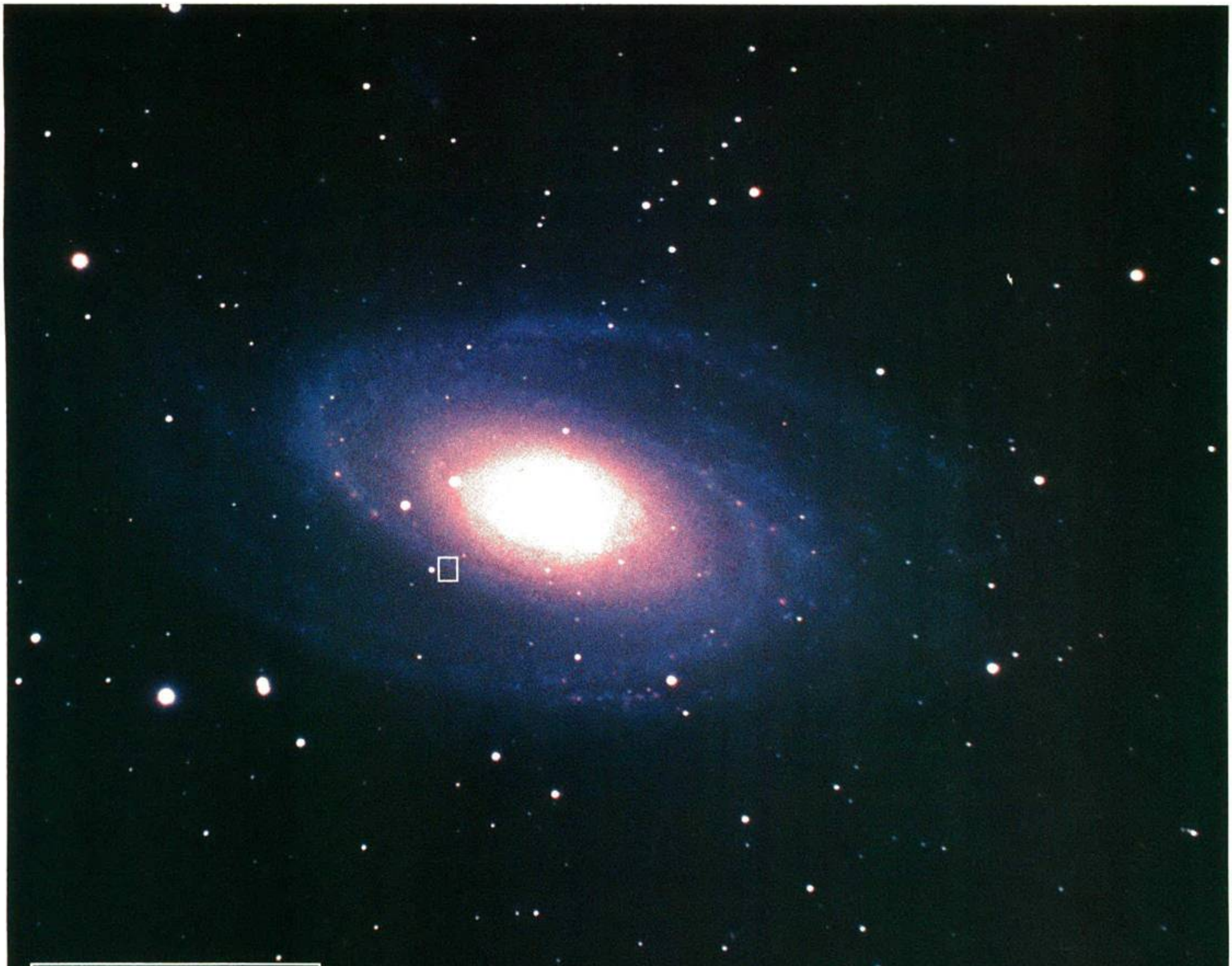
Although stars commonly eject surface material as they age, the extreme mass loss of the progenitor of SN 1993J took astronomers by surprise. For most of its last million years, the progenitor of 1987A (Sanduleak −69°202) was a bloated red supergiant, puffing gas from its surface like a wind. The star lost so much mass (about five of its original 20 solar masses) that in the last hundred thousand years of its life it shrank to become a blue supergiant, before exploding as supernova 1987A.

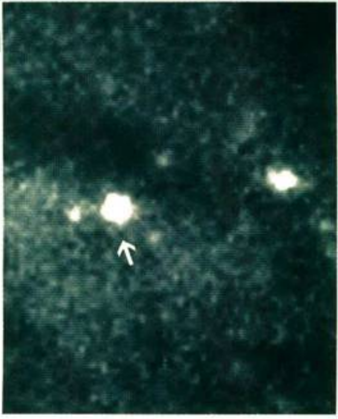
The precursor of SN 1993J certainly ejected some of its mass in wind, but many researchers think something else also had to act to strip most of the star's mass. They believe the gravitational pull of a binary companion of SN 1993J stole material from the dying star. The small companion may become detectable when the brightness of the supernova subsides several years from now.

Even if we never see a companion, astronomers found compelling X-ray and radio evidence that a nebulous cloud surrounds SN 1993J. This cloud consists of hydrogen gas ejected slowly by the supergiant star during the last million or so years. As the debris from the supernova explosion expands into the cloud and collides with the gas, it emits radio waves and X rays.

On April 2, just five days after García's discovery, a team at the Very Large Array outside Socorro, New Mexico, detected the first radio signals from SN 1993J. At the same time, astronomers using Japan's Advanced Satellite for Cosmology and Astrophysics and the European ROSAT satellite also detected it.

Again, researchers saw a striking difference between SN 1987A and SN 1993J. Radio and X-ray emissions were weak from SN 1987A because the fast moving blue supergiant wind swept the immediate environs fairly





ASTRONOMERS HAVE IDENTIFIED the star that exploded as a reddish yellow supergiant, marked with an arrow in the close-up photo at left taken before the supernova outburst.

Tony and Daphne Hallas

clean. The strong emissions from SN 1993J showed that the slowly moving wind of its reddish yellow supergiant progenitor, abetted by the gravitational pull of a companion star, surrounded the star with more material.

Looking Ahead

Astronomers have just begun to analyze and interpret the data from SN 1993J. But already the evidence shows the supernova is strikingly different from SN 1987A. Both SN 1987A and SN 1993J started as stars of 15 to 20 times the mass of the Sun but their life histories, if we read them correctly, diverged from the moment of birth. SN 1987A lived alone, lost about one quarter of its mass through stellar winds, and then ejected most of its material in a final convulsive burst. SN 1993J, on the other hand, may have had a companion star close by. As a result, it lost the majority of its material to its companion and to stellar winds, leaving only about a quarter of its original mass to be hurled out in the final explosion.

The two bright supernovae that have graced our skies in the past decade, therefore, seem to be a study in contrasts. And neither of the progenitors was quite what astronomers expected from their theories of stellar aging. Far from closing the book on supernova research, SN 1993J has made researchers look critically at their theories. Now they scan the skies expectantly for the next bright supernova to test their new ideas. If SN 1987A and SN 1993J are any indication, we may not have long to wait. □

Laurence A. Marschall is a professor of physics at Gettysburg College. This article is adapted from his book The Supernova Story *(Princeton University Press, 1994).*

SKY ALMANAC

February 1994

Mercury Bright After Sunset

The innermost planet puts on a good show in the evening sky during early February. At greatest elongation on February 4, Mercury shines brightly at magnitude –0.5 and appears 11° above the west-southwestern horizon 30 minutes after the Sun sets.

The Moon Joins Spica

The waning gibbous Moon passes near the 1st-magnitude star Spica on both February 1 and 28. The night of the 28th offers a better view for North American observers because the objects lie above the horizon at closest approach, when they pass less than 1° from each other.

Catch the Elusive Zodiacal Light

After the last glow of twilight fades from the evening sky, look toward the west for the ethereal glow of the zodiacal light. Evenings in February and March are the best times to see this faintly glowing pyramid of milky-white light, but you'll need a clear sky and a dark observing site.

Spend Time with Algol

With the constellation Perseus nearly overhead after darkness falls, February is a perfect time to follow the brightness changes of that constellation's second-brightest star, Algol. Every 68.8 hours Algol dims by 70 percent as a faint companion star passes in front of it and blocks some of its light from our view.

Tracking Comet Shoemaker-Levy 9

Now just five months from colliding with Jupiter, Comet Shoemaker-Levy 9 continues to pace the giant planet's motion through western Libra. You can find the comet glowing faintly at magnitude 14 about 3° southwest of Jupiter.

CALENDAR OF EVENTS

1 Asteroid Thalia is at opposition
The Moon passes 1.0° south of Spica, 5 p.m. EST
Mercury passes 1.3° north of Saturn, 11 p.m. EST

3 The Moon passes 3° south of Jupiter, 3 a.m. EST
Last Quarter Moon is at 3:06 a.m. EST

4 Mercury is at greatest eastern elongation (18°)
The Moon passes 3° north of Neptune, 3 a.m. EST
The Moon passes 5° north of Uranus, 7 a.m. EST

9 Comet Encke is at perihelion

10 New Moon is at 9:30 a.m. EST

15 The Moon is at apogee (251,643 miles from Earth), 8:35 p.m. EST

18 First Quarter Moon is at 12:47 p.m. EST

20 Mercury is in inferior conjunction

21 Saturn is in conjunction with the Sun

25 Full Moon is at 8:15 p.m. EST

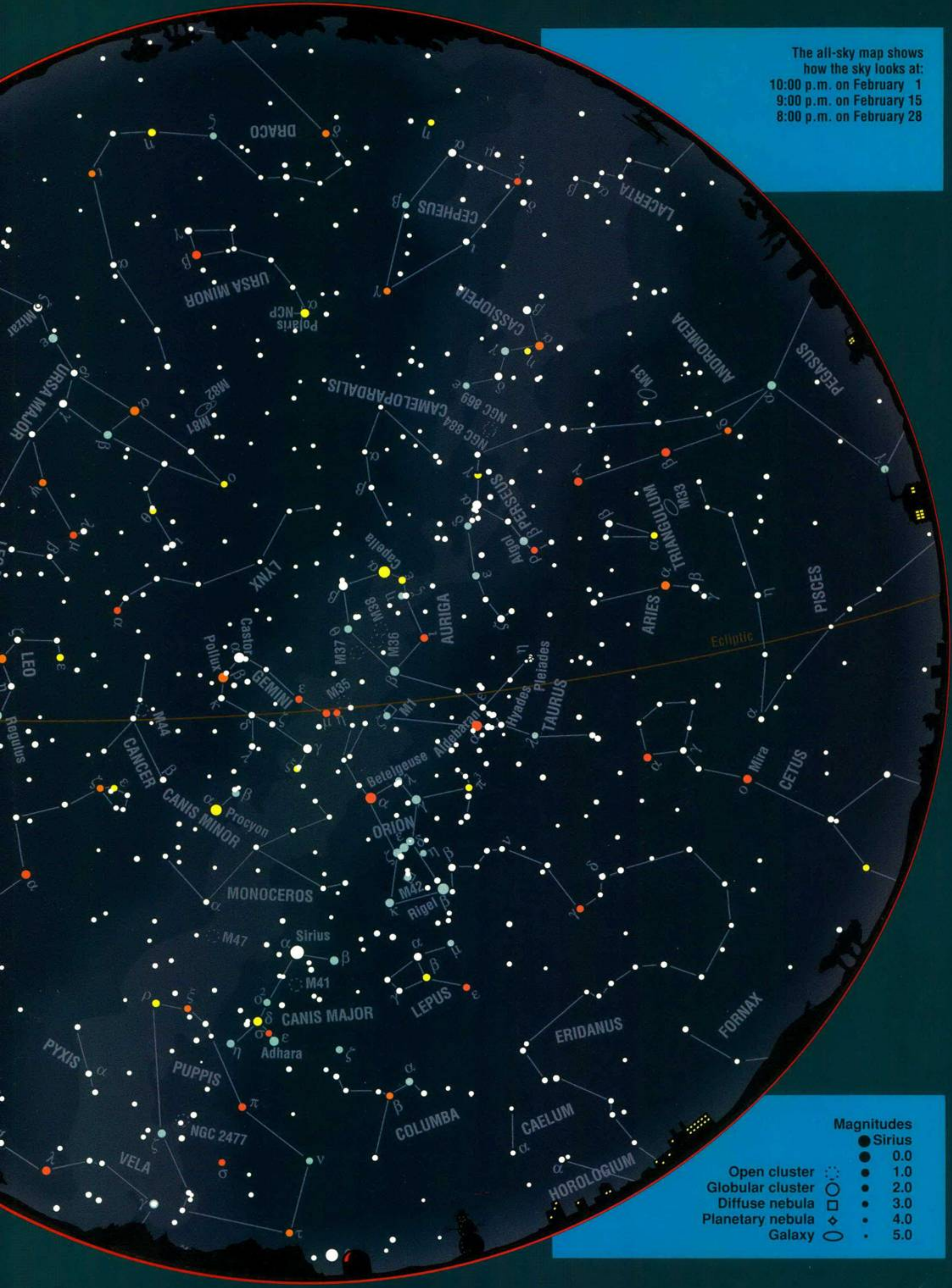
26 Mercury passes 4° north of Mars, 8 p.m. EST

27 The Moon is at perigee (224,840 miles from Earth), 5:09 p.m. EST

28 Jupiter is stationary
The Moon passes 0.7° south of Spica, midnight EST

BOOTES
M51
CANES VENATICI
COMA BERENICES
NGP
M64
Denebola
M66
M65
VIRGO
SEXTANS
CRATER
HYDRA
ANTLIA

The all-sky map shows
how the sky looks at:
10:00 p.m. on February 1
9:00 p.m. on February 15
8:00 p.m. on February 28


DRACO
CEPHEUS
LACERTA
URSA MINOR
Polaris
NCP
Mizar
CASSIOPEIA
ANDROMEDA
PEGASUS
M31
URSA MAJOR
M82
M81
CAMELOPARDALIS
NGC 869
NGC 884
PERSEUS
Algol
TRIANGULUM
M33
LYNX
Capella
AURIGA
M38
M36
M37
ARIES
PISCES
Ecliptic
Castor
Pollux
GEMINI
M35
M1
LEO
Regulus
M44
CANCER
Aldebaran
Hyades
Pleiades
TAURUS
Betelgeuse
Mira
CETUS
CANIS MINOR
Procyon
ORION
MONOCEROS
M42
Rigel
M47
Sirius
M41
LEPUS
CANIS MAJOR
Adhara
PYXIS
PUPPIS
ERIDANUS
FORNAX
COLUMBA
CAELUM
NGC 2477
VELA
HOROLOGIUM

Magnitudes
● Sirius
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0

Open cluster ⁛
Globular cluster ○
Diffuse nebula □
Planetary nebula ◇
Galaxy ⬭

SKY ALMANAC

by Deborah Byrd and Rick Shaffer

Of the five bright planets, Mercury is the one seen least often. Named for the fleet-footed messenger god of Roman mythology, the innermost planet races around the Sun once every 88 days. It appears in our sky some half-dozen times each year, alternating between the eastern sky before dawn and the western sky after sunset. But because each apparition is short and the planet never strays far from the Sun, you must look carefully — or when Mercury is at its best — or pay the price of missing it.

This month brings one of Mercury's two best evening apparitions of 1994. You can glimpse the planet shining low in the twilight sky during the first ten days of February. Greatest elongation — when Mercury is at its greatest apparent distance from the Sun — comes on February 4. Then the planet shines at magnitude –0.5, making it the brightest object low in the west-southwest after sunset.

You can start to look for Mercury about 30 minutes after the Sun sets. Choose an evening when no haze or mist lurks near the horizon and pick an observing site free of foreground obstructions. This month you can find Mercury partly by the company it keeps. It has a conjunction with Saturn on the evening of February 1, when it passes 1.3° due north of the ringed planet. Saturn appears noticeably fainter than Mercury, shining at magnitude 0.9.

Afterward Saturn slides into the twilight glare and disappears from view for several weeks as it travels behind the Sun as seen from Earth. Mercury hangs on a little longer, long enough for the young crescent Moon to pass nearby on February 11. If on that night you gaze at Mercury and the Moon with your telescope, you'll find a little crescent planet with a phase similar to the big crescent Moon. Some people are surprised when they see Mercury looking like a tiny crescent Moon. But this world travels on an orbit that carries it between Earth and the Sun, so its lit half must occasion-

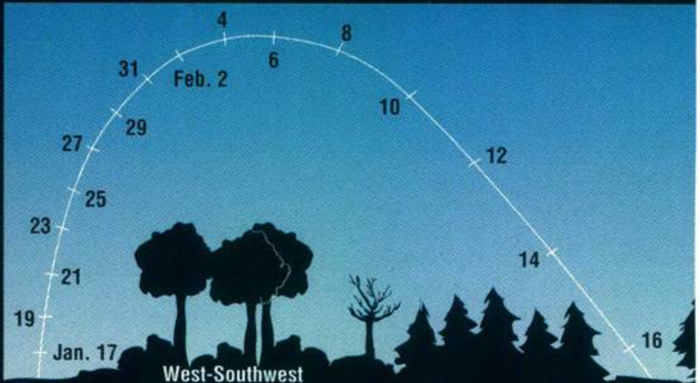
G. Tanzer

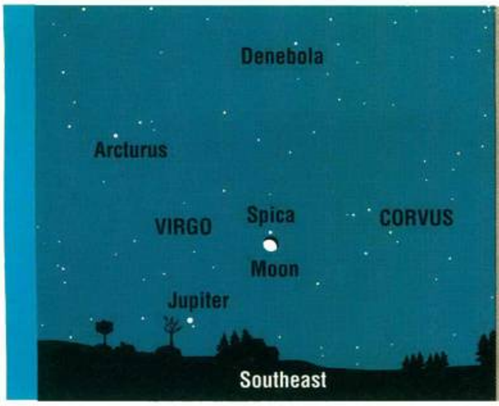
Mercury Brightens the Evening Sky

February offers an excellent evening appearance of Mercury. Despite shining at magnitude 0 or brighter, however, the innermost planet is elusive because it never strays far from the horizon. You'll need an observing site with an unobstructed horizon. Binoculars will help you spot the planet initially; steady them by leaning your elbows on a fence post or the roof of a car.

You can begin your search in the latter part of January. Thirty minutes after sunset on the 25th, the planet lies 6° above the west-southwestern horizon. On the evening of February 1, Mercury passes just over 1° from Saturn, which glows more dimly at magnitude 0.9. Mercury is best placed for viewing on the 4th, when it lies 18° east of the Sun, the maximum for this evening appearance. For an observer at 40° north latitude, the planet then lies 11° above the horizon 30 minutes after sunset. By the 11th, Mercury is in the middle of its plunge back toward the horizon. You might be able to glimpse it, however, just below and to the left of the waxing crescent Moon.

For telescope observers, Mercury's most visually exciting feature is its rapidly changing phase. On February 1, the planet's 6.3"-diameter disk appears 69 percent lit. But Mercury's phase wanes rapidly as the planet approaches and then passes greatest elongation. On the 4th, Mercury appears 53 percent lit and on the 11th, with the Moon close by, the planet shows a 20-percent-lit crescent.





The Moon Passes Spica

This month the Moon twice passes near 1st-magnitude Spica in the constellation Virgo. The waning gibbous Moon first overtakes Spica on the morning of the 1st, when it passes 1.0° south of the star. Unfortunately the closest approach occurs when the two are below the horizon from North America, so that morning you'll see them a few degrees apart.

The second meeting of the pair comes on the night of February 28/March 1 and is much better placed for North American observers. At midnight eastern time (shown at left), the Moon passes 0.7° south of the star. Binoculars or a small telescope should give you the best view. With a scope, chose a low-power eyepiece, locate the north limb of the Moon, and then move the scope just a bit north to see Spica too.

ally face away from us.

If you have an eagle eye, you may spot Mercury passing near Venus at midmonth, as Mercury slides into the Sun's glare and Venus struggles out of it. When viewed through a telescope, Mercury appears as a thin crescent but Venus shows no phase at all. That's because it has been traveling on the far side of the Sun from us and we are now seeing its fully lit half. Mercury shows a phase because it is preparing to pass between the Sun and Earth on February 20.

Bright planets such as Mercury and Venus are easy to see from cities. You can often see them after sunset or before sunrise, while driving in your car or while looking at the sky from a wide-open field or parking lot. But another evening "object" this month can't be seen from the city. The zodiacal light requires the darkest of skies.

In a dark sky in late winter and early spring, the zodiacal light appears as a milky-white cone rising from the western evening horizon. From the tropics, it looks quite bright and there are tales of its fantastic, eerie luminescence. From midnorthern latitudes, however, the zodiacal light is subtle and hard to see under less-than-ideal conditions. How can you recognize this subtle glow? First, wait until all traces of twilight have left the evening sky. Then look for a soft light coming into view in the west — a glow like that of a town just over the horizon in a place where there is no town. That's it! Your best chance to see the zodiacal light comes when the Moon is gone from the evening sky, in early February and early March.

The asteroid 23 Thalia reaches opposition on February 1. That means it's opposite the Sun from Earth and appears above your local horizon all night long. This opposition brings Thalia closer to Earth than

Seeing the (Zodiacal) Light

Mercury appears more conspicuous than usual this month because the path that the planets follow in the sky, the ecliptic, makes a steep angle with the western horizon after sunset. Thus the angular separation of Mercury from the Sun translates almost entirely into altitude above the horizon.

For the same reason, February is the ideal time to observe a subtle but beautiful phenomenon, the zodiacal light. There's a big difference between seeing Mercury and the zodiacal light, however: Mercury is small and relatively bright, while the zodiacal light is large and dim.

If you're observing from a dark site, you can find the zodiacal light after Mercury has set and twilight has faded. But because the Moon's light drowns out the subtle zodiacal light, be sure to search before the Moon barges into the evening sky.

Look for a broad, cone-shaped glow that tilts toward the south. The base of the cone is 20° to 30° wide and lies on the western horizon. It extends along the ecliptic for about three times that distance, although you'll need exquisite conditions to see the glow extend 90°.

The zodiacal light derives from dust particles in the plane of the ecliptic that scatter the Sun's light randomly in all directions. It's dim because our eyes intercept only a tiny fraction of this scattered light.

R. Grover

usual because it takes place when Thalia is near perihelion, the closest point in its orbit to the Sun.

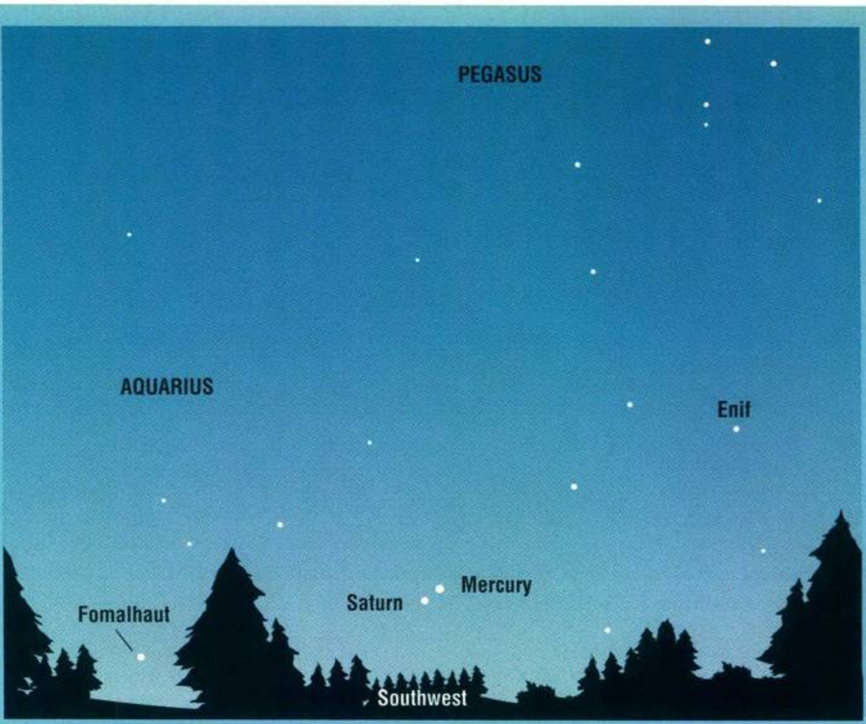
Although opposition and perihelion are unrelated events, they combine this month to make Thalia brighter than normal. Opposition is a geocentric, or Earth-centered, event that takes place when Earth passes between the asteroid and the Sun. Perihelion is a heliocentric, or Sun-centered, event. It comes once each time Thalia orbits the Sun every 4.3 Earth years. When Earth whizzes between the Sun and Thalia on February 1, the asteroid is just two weeks past its closest approach to the Sun. Hence Thalia is closer to Earth than usual and, at magnitude 9.2, glows brighter than at most oppositions. Use binoculars or a small telescope to spot it against the star background as it crosses from Leo Minor into Lynx.

After the planets low in the west have set, the zodiacal light has faded from view, and you've spotted Thalia against the background stars, you might decide to look for other bright planets — but you won't find any. From our vantage point, all the planets except Jupiter and Pluto now cluster in the general direction of the Sun. Thus most of the planets cross our sky at the same time as the Sun, in daylight.

You can see Jupiter this month, however, and a splendid sight it is. It rises in the middle of the night and lies high in the south before sunrise. The giant planet shines brilliantly at magnitude –2.1 and appears as a bold, cream-colored light among the stars of Libra. Right next to it you'll see Libra's second-brightest star, 3rd-magnitude Zubenelgenubi, though Jupiter shines nearly 100 times brighter.

Two stars brighter than Zubenelgenubi lie in the

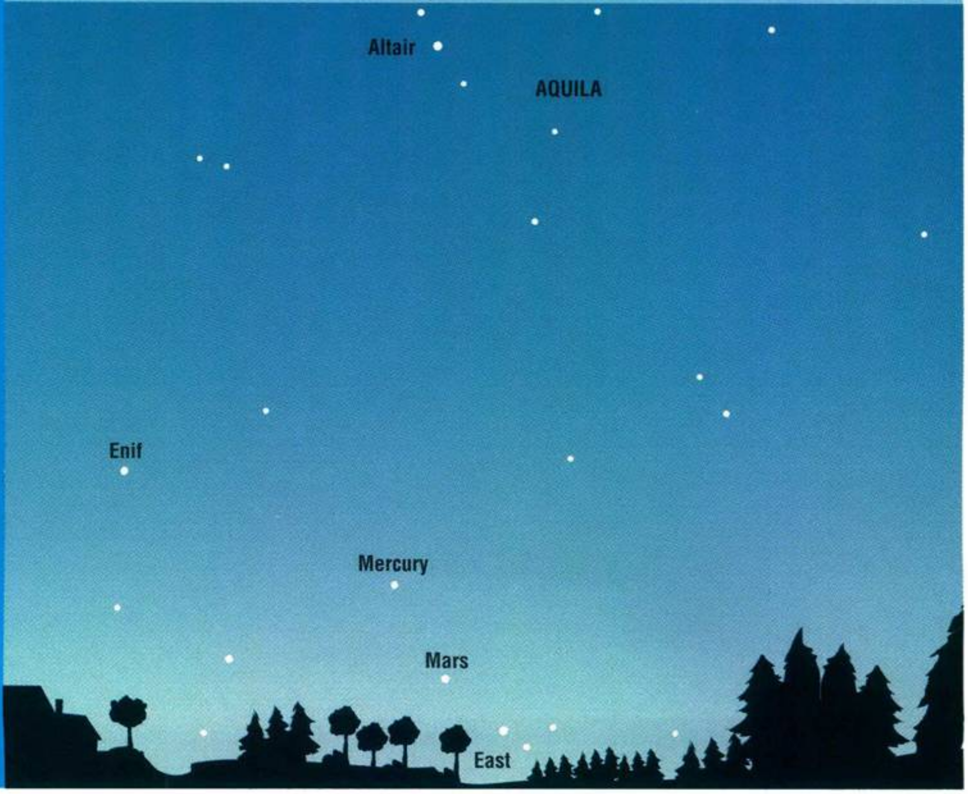
(continued on page 52)



Mercury Joins Saturn And Mars

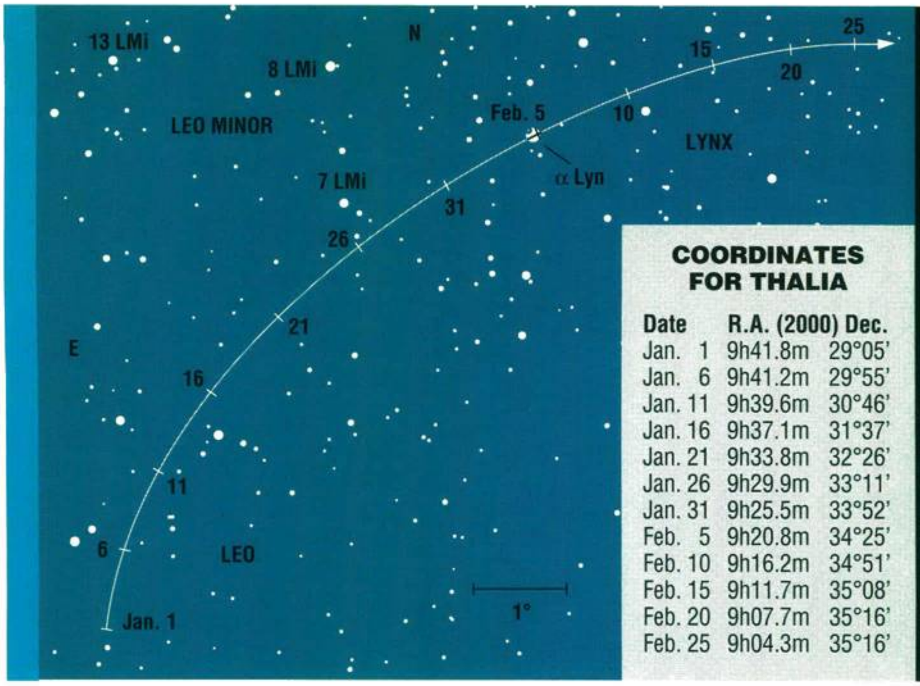
A close approach to the planet Saturn punctuates Mercury's evening appearance in early February. The two appear just 1.3° apart on the 1st (above), but they remain near one another for a few days. This is a good opportunity to compare the pale yellow of Mercury's disk with the golden color of Saturn's. (However, the two lie only 10° above the horizon 30 minutes after sunset, so you likely won't see any further detail.)

Following Mercury's evening appearance, the fast-moving planet passes in front of the Sun and then shoots into the morning sky, appearing there at the end of February. You then may be able to spot Mercury as it passes Mars. The two come closest on the 27th, when they appear 4° apart. For an observer at 40° latitude, the planets lie 3° above the east-southeastern horizon 20 minutes before the Sun rises (below).



Asteroid Thalia Grows Bright

This month's best asteroid is 23 Thalia, which on February 1 appears opposite the Sun in our sky and remains up all night. The 110-kilometer-diameter chunk of rock shines at magnitude 9.2 at opposition, fully two magnitudes brighter than at its last opposition in September 1992. From January into February, the asteroid moves from northern Leo, through southwestern Leo Minor, and into Lynx, passing less than 1' from the 3rd-magnitude star Alpha (α) Lyncis on the evening of February 5. (Positions in the finder chart and table are given for 11 p.m. EST, 10 p.m. CST, 9 p.m. MST, and 8 p.m. PST.)



COORDINATES FOR THALIA

Date	R.A. (2000)	Dec.
Jan. 1	9h41.8m	29°05'
Jan. 6	9h41.2m	29°55'
Jan. 11	9h39.6m	30°46'
Jan. 16	9h37.1m	31°37'
Jan. 21	9h33.8m	32°26'
Jan. 26	9h29.9m	33°11'
Jan. 31	9h25.5m	33°52'
Feb. 5	9h20.8m	34°25'
Feb. 10	9h16.2m	34°51'
Feb. 15	9h11.7m	35°08'
Feb. 20	9h07.7m	35°16'
Feb. 25	9h04.3m	35°16'

Tracking the Demon Star with Your Naked Eye

For beginning stargazers, one of the most unexpected aspects of the sky is that some stars vary in brightness. And of all these variable stars, none is easier to follow than Algol.

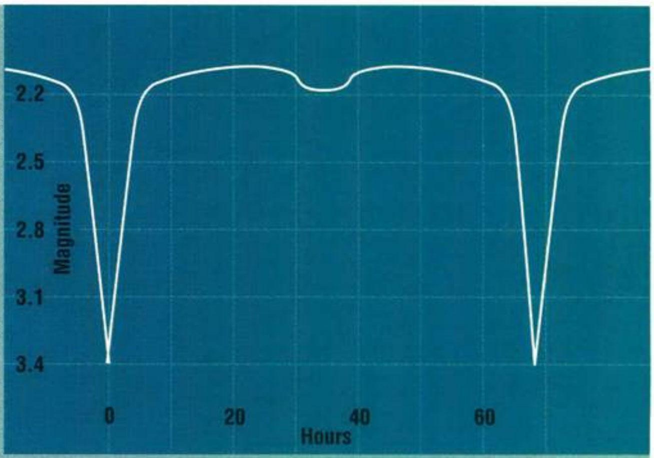
Algol represents the eye of the monster slain by the hero Perseus in whose constellation Algol lies. You can locate Perseus with the help of the Star Dome map at the beginning of this section.

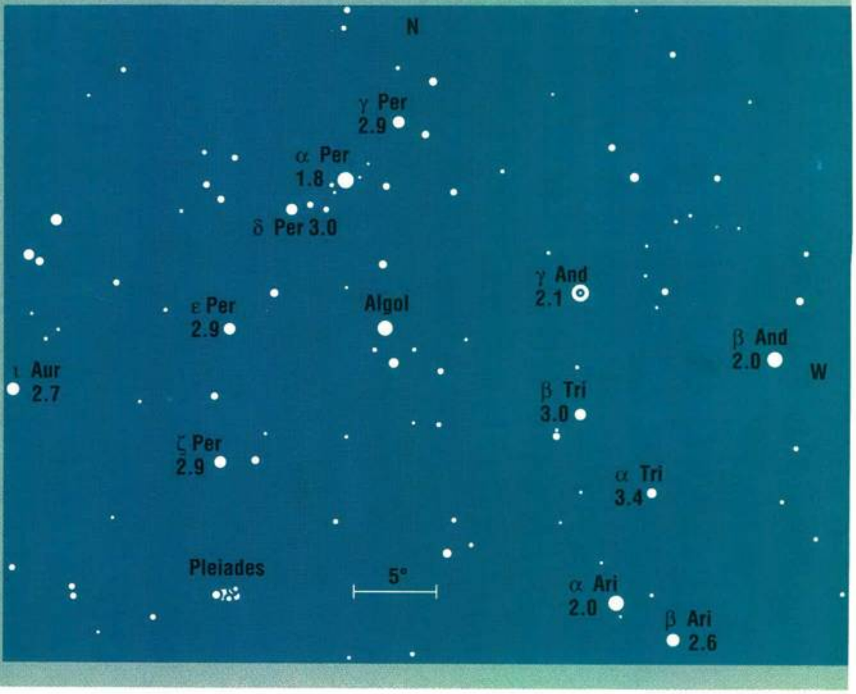
Algol consists of two stars revolving around one another. One star is much fainter than the other, and when it passes in front of the brighter star, the combined light of the two drops noticeably. These eclipses occur every 2 days, 20 hours, and 49 minutes and last for about 10 hours. When not in eclipse, Algol shines at magnitude 2.1, some 3.3 times brighter than at mid-eclipse when the magnitude falls to 3.4.

The map at right shows Algol and many nearby stars of constant brightness. Estimating Algol's brightness is easy. Just find two stars that bracket Algol's brightness. If one star's magnitude is 2.9 and the other's is 2.7 and if Algol appears midway between the two, the "Demon" must be at magnitude 2.8. The table gives the times this month when Algol is at minimum brightness so that you know when to expect the changes.

MINIMA OF ALGOL

Date	EST
February 2	12:11 p.m.
February 5	9:00 a.m.
February 8	5:49 a.m.
February 11	2:39 a.m.
February 13	11:28 p.m.
February 16	8:17 p.m.
February 19	5:07 p.m.
February 22	1:56 p.m.
February 25	10:45 a.m.
February 28	7:35 a.m.





south at dawn too, on either side of the giant planet. One is Spica in the constellation Virgo; the other is Antares in the constellation Scorpius. Together, these objects make a lovely sight for early risers this winter.

On the morning of February 3, look for the Last Quarter Moon passing near Jupiter. The Last Quarter Moon marks the general direction of Earth's orbital motion around the Sun. In other words, if you could anchor the Last Quarter Moon in space, Earth would smash into it in just a few hours as our world whips around the Sun at 18 miles per second.

Thus Jupiter this month provides a somewhat more constant — albeit more distant — marker for the direction of Earth's motion. Perhaps you'll think about the movement of worlds in space while climbing behind the wheel for another morning's drive to rejoin the workaday world.

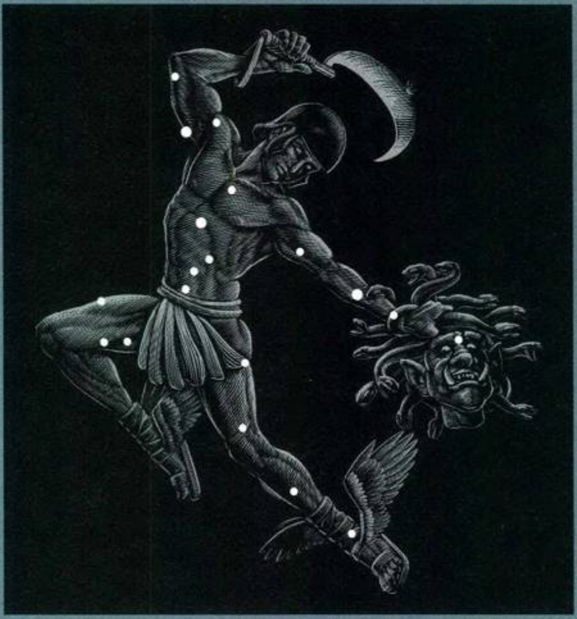
February's Planets

No plethora of planets greets backyard observers this month, bright or otherwise. As during the last couple of months, most of the planets congregate in the general direction of the Sun. But this month at least, the planets show some movement toward coming back into view.

Mercury appears low in the west-southwest after sunset. On February 4 it reaches greatest elongation, when it lies 18° east of the Sun and shines at magnitude –0.5. Mercury passes 1.3° north of **Saturn** on February 1. Although the ringed planet shines brightly at magnitude 0.9, it's not easy to see against the twilight glare. It disappears from view after the first week of

THE STARRY SKY

by Deborah Byrd



Keith Ward

The constellation Perseus the Hero lies nearly overhead after sunset on February evenings. From a dark location, you can see the starlit trail of the winter Milky Way passing through Perseus, which makes this constellation a rewarding place to turn your binoculars.

The brightest star in Perseus is Alpha (α) Persei, also called Mirfak. It shines at magnitude 1.8 from a distance of about 620 light-years. Mirfak is part of a J-shaped asterism known as the Segment of Perseus. With binoculars, you'll see that Mirfak itself is surrounded by a group of blue-white stars called the Alpha Persei association.

Beta (β) is Perseus' second-brightest star. It usually shines at magnitude 2.1 from a distance of 95 light-years. This is Algol, the "Demon Star," an eclipsing binary whose light variations can be seen with the naked eye (see previous page).

Perseus also contains the famous Double Cluster — two large open star clusters that nearly overlap — individually known as h and Chi (χ) Persei (NGC 869 and NGC 884). On a dark night you can easily see these swarms of stars with the naked eye about one-third of the way between the northern tip of Perseus and that constellation's western neighbor, Cassiopeia.

In mythology, Perseus was a brave and handsome boy who lived with his mother on an island. The island was ruled by wicked King Polydectes, who was smitten with Perseus' mother and wanted to marry her. But the boy stood in his way, so Polydectes sent him off on a difficult quest — to find the Gorgon Medusa and chop off her head.

This was no easy task. Medusa had snakes instead of hair and looked so horrible that anyone who gazed at her turned to stone instantly. Perseus turned to the gods, and Athena gave him a magic helmet — the Cap of Darkness — that would make him invisible. She also loaned him her polished shield and warned him to gaze only at Medusa's reflection. The messenger god Mercury gave Perseus a pair of winged sandals — the Shoes of Swiftness — and a magic sword.

Perseus found Medusa in her lair, where she lay asleep. He put on the Cap of Darkness, swooped down like the wind, and — looking at her image in the shield — swung the magic sword and chopped off her head.

Fleeing homeward he heard screams and saw a beautiful princess, Andromeda, tied to a rock by the sea, where the sea monster Cetus was preparing to eat her. Perseus "stirred up the dust in heaven" in his rush to rescue Andromeda. This may be a reference to the starry Milky Way in this vicinity of the heavens.

Perseus pulled Medusa's head from a bag, and Cetus became a rock by the sea. The hero and the princess, of course, fell in love, but Perseus had one more score to settle. He headed back to his home island and appeared at Polydectes' court. Perseus shouted, "Here is your gift!" and held up Medusa's head, turning the evil king and his supporters to stone.

Afterward, Perseus and Andromeda lived happily, ruled wisely, and had many children. One of their great-grandsons was Hercules. Perseus' ending is described by William Tyler Olcott in his famous book *Star Lore of All Ages*: "At his death, it is said, he was transported to the starry skies, where he appears with upraised sword, holding the severed head of the Medusa up to the gaze of all mankind, for all time."

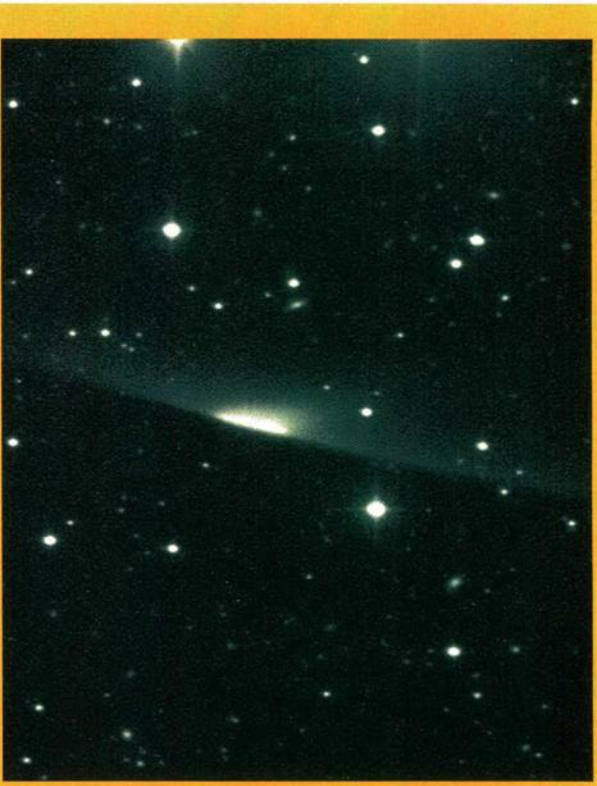
Keeping Tabs on Shoemaker-Levy 9

Comet Shoemaker-Levy 9 is scheduled to collide with Jupiter this coming July. Although the comet glows faintly at magnitude 14, you might be able to glimpse it if you have a large telescope. This month the comet remains less than 3° southwest of Jupiter among the background stars of western Libra.

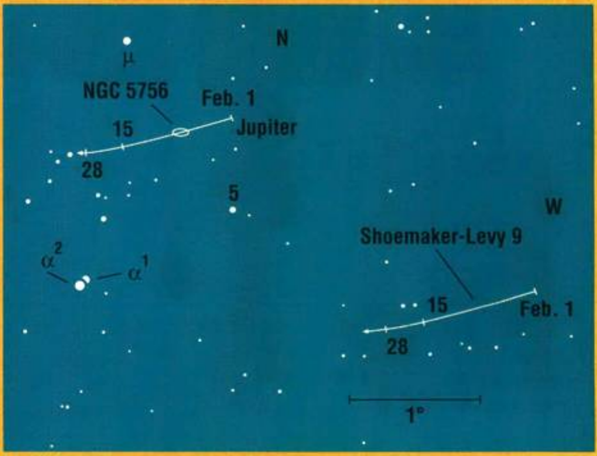
To spot the comet, you'll likely need a 12-inch or larger telescope, an excellent observing site, and crystal-clear weather. (Imaging the comet's field will improve your odds of finding the faint object.) Your best chance to see the comet comes when it and Jupiter are high in the sky shortly before morning twilight begins.

The easiest way to locate Shoemaker-Levy 9 is to use Jupiter as a starting point. (Try using a neutral-density filter to cut down on the planet's light or else you may damage your dark adaption and find it harder to spot the comet.)

Use the table of offsets below to get to the right area. Then insert an eyepiece that gives an exit pupil of about 2 millimeters. (A 12.5-inch scope would be best at around 160x, a 16-inch scope at about 200x, and a 20-inch at 250x.) Such a power retains a reasonably wide field of view while knocking sky glow below your eye's level of detection. Once you've found the spot, look for a fuzzy patch of light and sketch the field around it. Then come back a night or two later and see if the nebulous glow has moved. If so, you've found the comet and gotten a jump on everyone who will be looking for it come July.



Jim Scotti



COORDINATES FOR COMET SHOEMAKER-LEVY 9

On this Date	Offsets from Jupiter West in R.A.	South in Dec.
February 1	**9m39s**	**1°20.8'**
February 6	**9m38s**	**1°21.4'**
February 11	**9m38s**	**1°21.9'**
February 16	**9m37s**	**1°22.2'**
February 21	**9m36s**	**1°22.5'**
February 26	**9m34s**	**1°22.6'**

February. Mercury remains visible after Saturn has gone, but by midmonth it too gets lost in the Sun's glare.

Meanwhile **Venus** returns to the evening sky in the latter half of February. (It becomes a brilliant object in the evening sky in March.) Although it remains very low in the west during bright twilight, Venus should catch your eye because it is so bright. It shines at magnitude –3.9, some five times brighter than Jupiter.

Speaking of **Jupiter,** it rises around midnight and appears high in the south before dawn. With Venus out of the way by then, the giant planet is the brightest object in the night sky besides the Moon. Jupiter shines at magnitude –2.1 and through a telescope displays a 38"-diameter disk. Notice that the disk appears wider than it does high. This squashed appearance arises because the gaseous world spins on its axis so fast, once every 10 hours.

The outpost planet **Pluto** rises shortly after Jupiter. Like Jupiter it lies in the constellation Libra, but at the far eastern edge. You'll need at least an 8-inch telescope to spot Pluto and even then it looks no different than a star. To recognize it, you must track its motion against the star background from one night to the next.

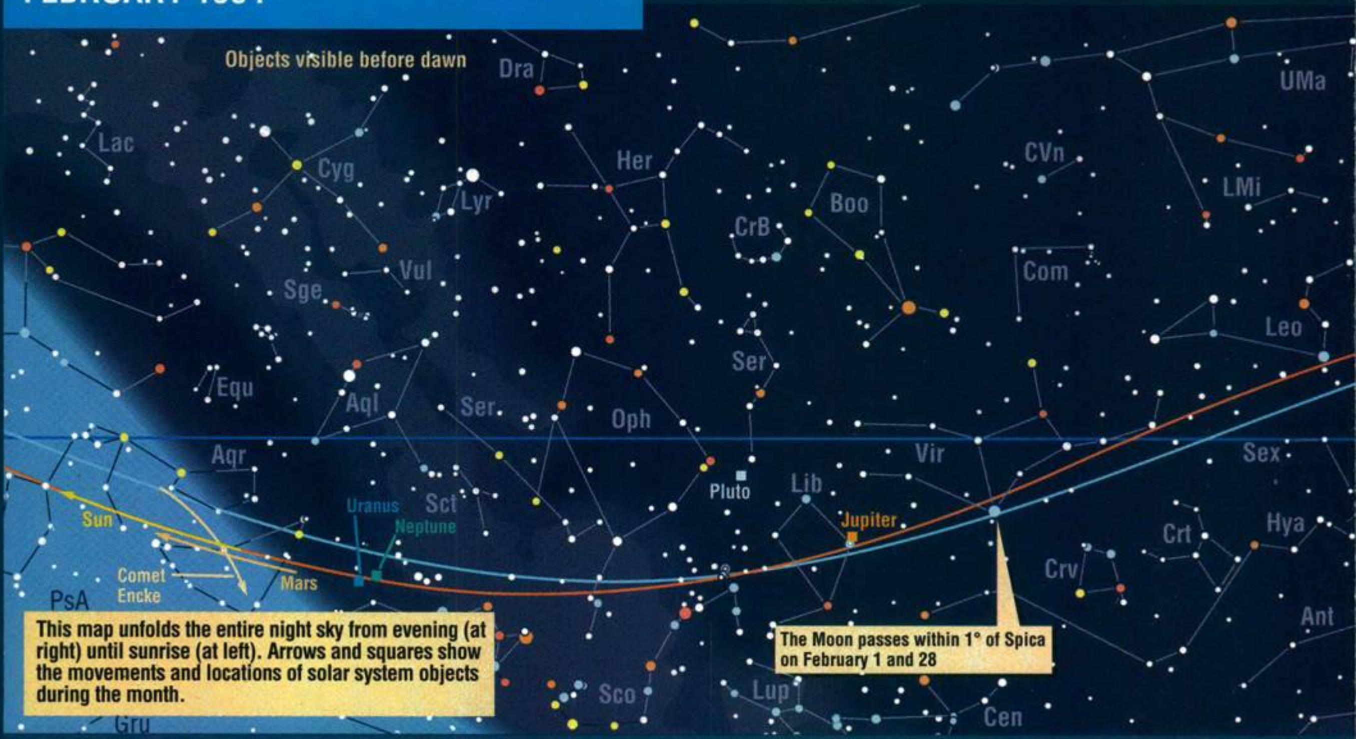
Although **Uranus** and **Neptune** are officially morning planets, they are too low in the southeast during twilight to bother with. Wait another month before searching for these outer worlds.

Mars is still traveling behind the Sun, on an extended holiday from our sky. Although you may spy the Red Planet very low in the east-southeast at the end of February, your chances of seeing it improve markedly come March and April. ☐

Deborah Byrd writes and produces the daily "Earth and Sky" radio series. Rick Shaffer is an engineer and writer living in Southern California.

SKY ALMANAC

FEBRUARY 1994


Objects visible before dawn
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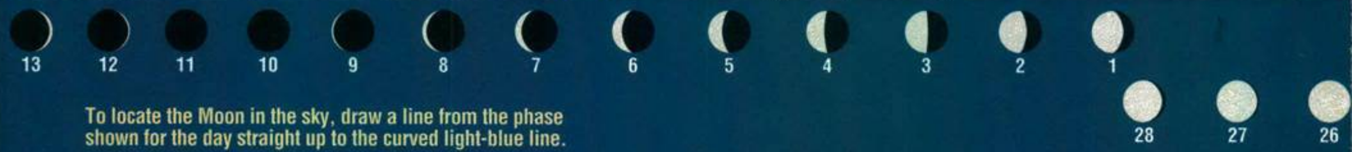
Aql
Ser
Oph
Sex
Aqr
Vir
Pluto
Lib
Uranus
Sct
Neptune
Jupiter
Hya
Sun
Crt
Crv
Comet Encke
Mars
PsA
Ant
Sco
Lup
Cen
Gru

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

The Moon passes within 1° of Spica on February 1 and 28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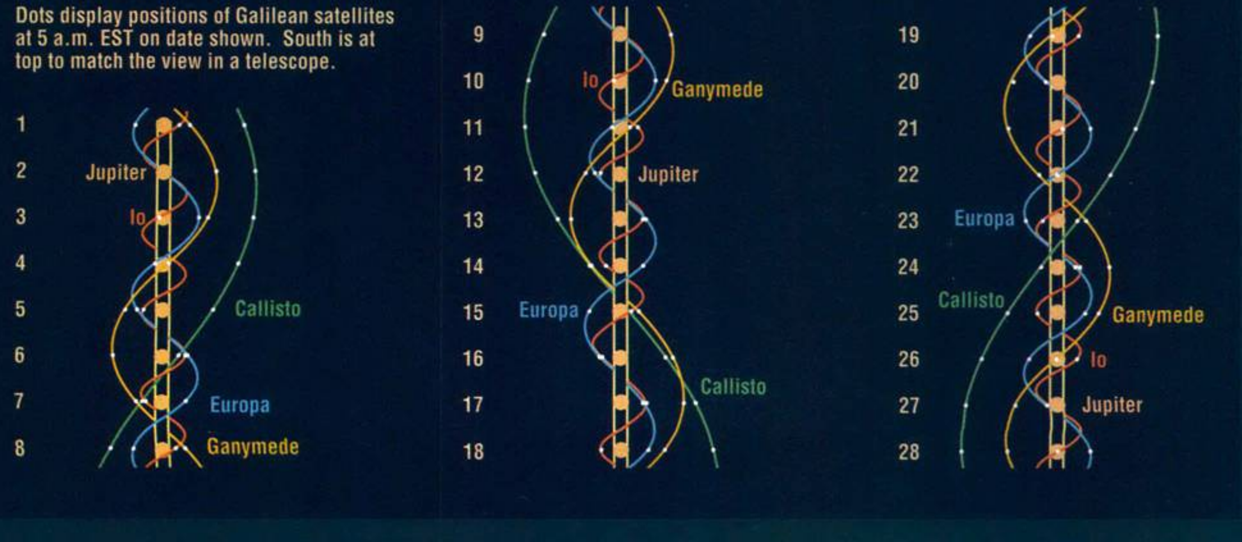
1
28
27
26

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

PLANETS	MERCURY	MERCURY	VENUS	MARS
Date	February 1	February 28	February 28	February 28
Magnitude	–0.8	2.0	–3.9	1.2
Angular Size	6.3"	10.2"	9.9"	4.0"
Illumination	69%	12%	99%	99%
Distance (AU) from Earth	1.061	0.659	1.680	2.323
Distance (AU) from Sun	0.320	0.395	0.726	1.390
Right Ascension (2000.0)	22h07.0m	21h42.4m	23h23.1m	21h47.6m
Declination (2000.0)	–12°02'	–10°42'	–5°30'	–14°29'

JUPITER'S MOONS

Dots display positions of Galilean satellites at 5 a.m. EST on date shown. South is at top to match the view in a telescope.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Io
Ganymede
Jupiter
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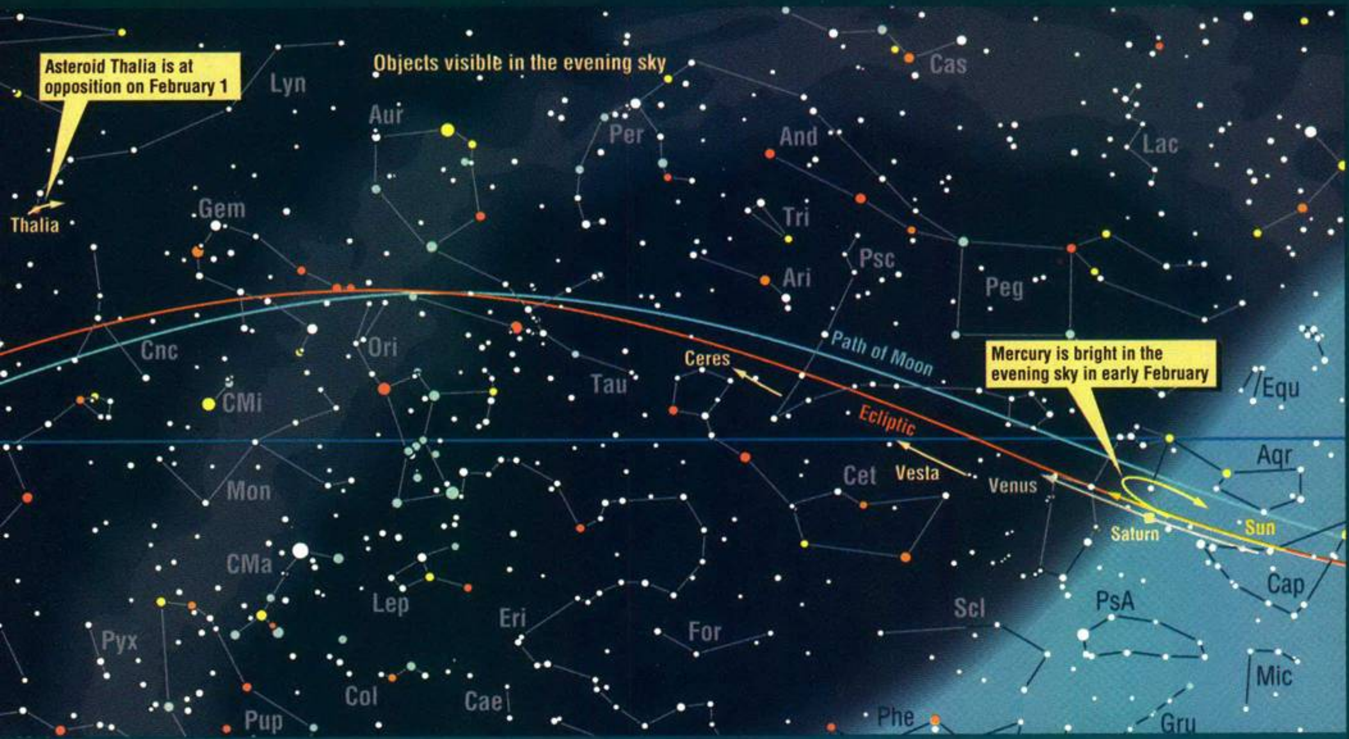
Io
Jupiter


Thalia
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Ecliptic
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Vesta
Venus
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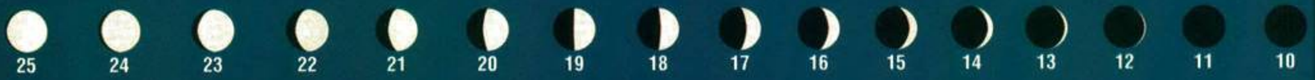
Asteroid Thalia is at opposition on February 1

Objects visible in the evening sky

Mercury is bright in the evening sky in early February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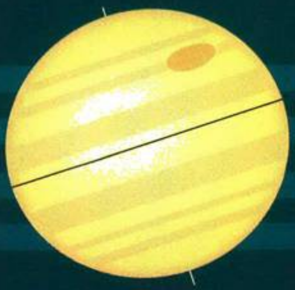
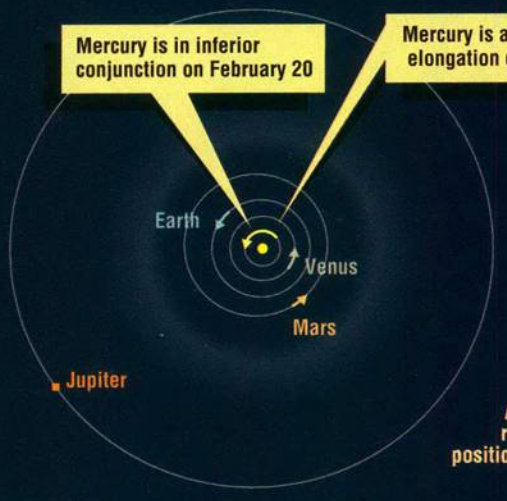


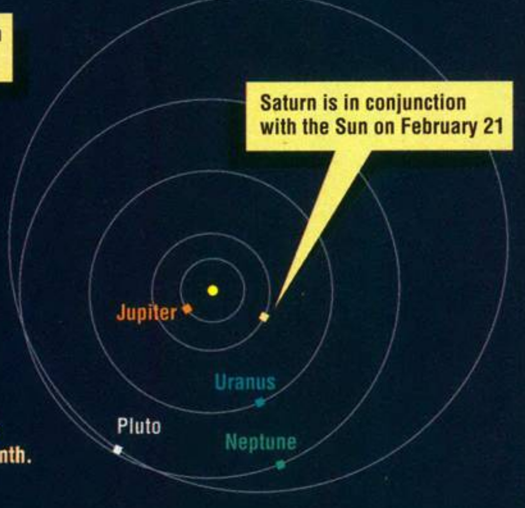
JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
February 15	February 1	February 15	February 15	February 15
−2.1	0.9	5.8	8.0	13.7
38.2"	15.5"	3.4"	2.2"	0.1"
99%	100%	100%	100%	100%
5.153	10.700	20.472	30.994	29.784
5.440	9.771	19.640	30.180	29.768
14h49.5m	22h12.1m	19h45.0m	19h35.4m	15h55.8m
−14°58'	−12°39'	−21°43'	−21°01'	−6°02'

THE PLANETS IN THEIR ORBITS


Earth
Venus
Mars
Jupiter

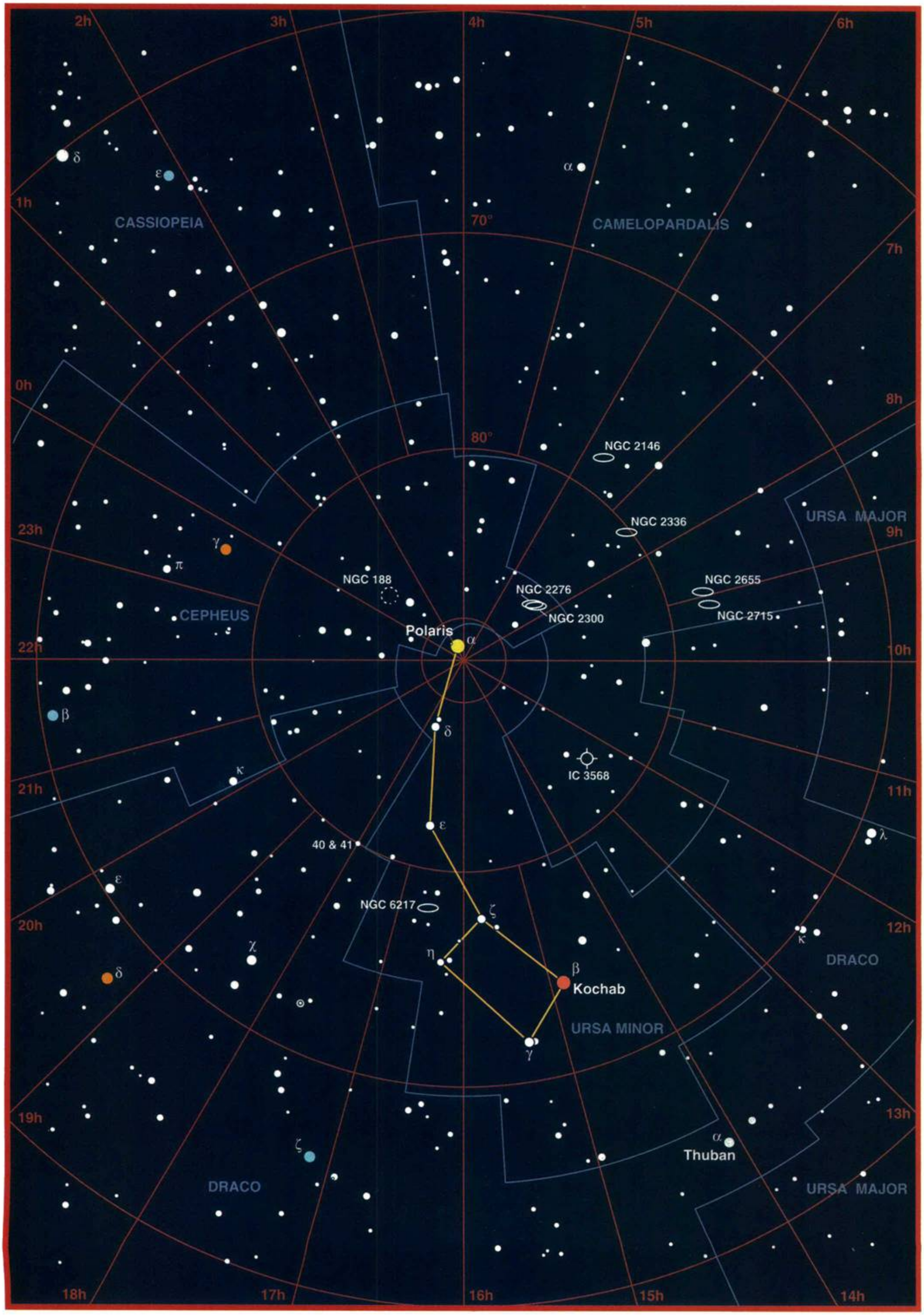
Mercury is in inferior conjunction on February 20

Mercury is at greatest eastern elongation on February 4


Jupiter
Uranus
Pluto
Neptune

Saturn is in conjunction with the Sun on February 21

Arrows and dots represent planets' positions during the month.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17h
16h
15h
14h
70°
80°
CASSIOPEIA
CAMELOPARDALIS
CEPHEUS
URSA MAJOR
URSA MINOR
DRACO
DRACO
URSA MAJOR
δ
ε
α
γ
π
β
κ
ε
δ
χ
ζ
NGC 2146
NGC 2336
NGC 188
NGC 2276
NGC 2300
NGC 2655
NGC 2715
Polaris
α
δ
IC 3568
ε
40 & 41
NGC 6217
ζ
η
β
Kochab
γ
λ
κ
α
Thuban

ASTRONOMY: Steven G. Davis

NORTH OF 75°

Travel into the northernmost reaches of the sky for a telescopic expedition across the galaxies, clusters, and nebulae of the celestial Arctic.

by Lee T. Macdonald

Every backyard astronomer can tell the season by the stars. In summer and winter, we look along the plane of the Milky Way toward the star clusters and nebulae of our Galaxy; in spring and autumn, we look out of the Milky Way toward other galaxies scattered throughout the universe. But one area of sky allows us to see deep-sky objects of both types year round. This is the region surrounding the central pivot of the northern sky, the north celestial pole.

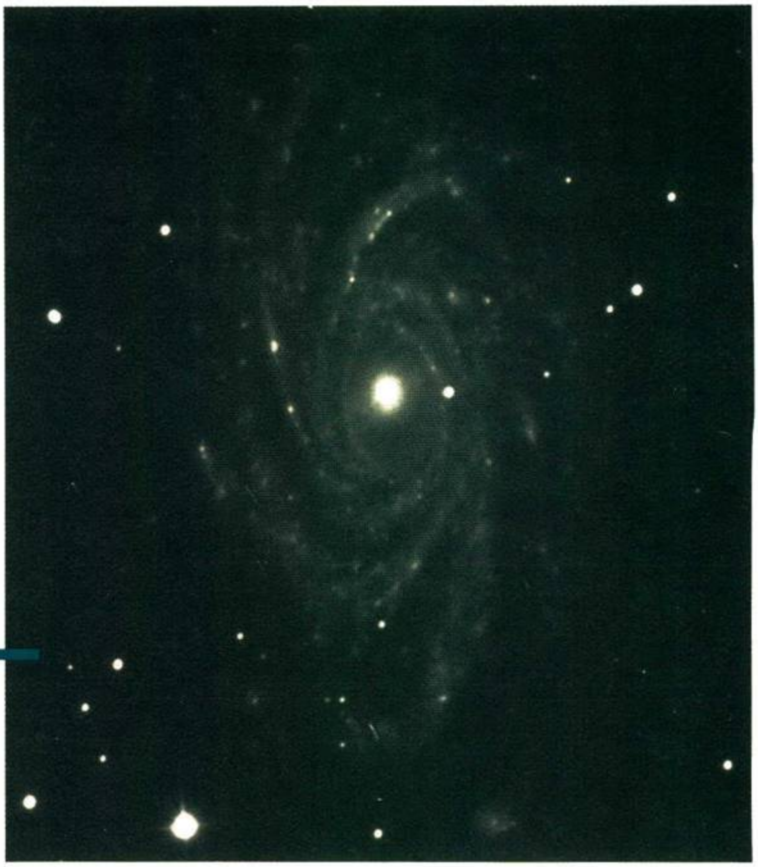
For observers in North America and Europe, the sky within 15° of the pole lies well above the northern horizon during every season. Several constellations reach up into this "Arctic" region, and each contains deep-sky objects suitable for a 6-inch or larger telescope. Join me on a voyage to the best of these objects, beginning with the bright star at the hub of the celestial Arctic.

Less than a degree from the north celestial pole lies **Polaris** (Alpha [α] Ursae Minoris), the North Star. Most backyard astronomers know Polaris marks the approximate position of the pole. Fewer know that Polaris is a double star. A generous 18" separates the 2nd-magnitude primary from its 9th-magnitude companion. On nights of steady seeing, a 2-inch refractor splits Polaris and apertures larger than this show the pair distinctly.

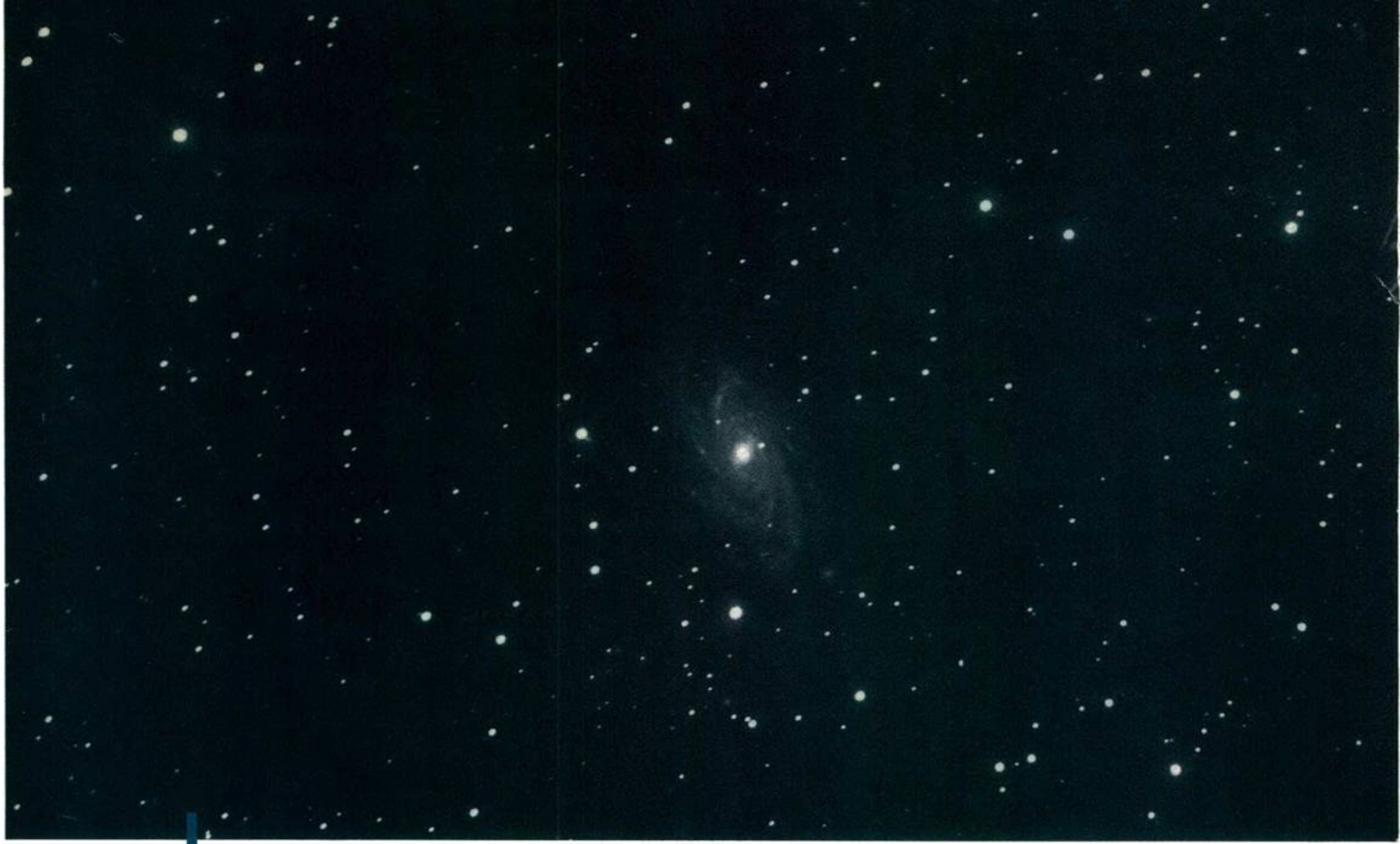
From Polaris move your telescope about 3° in the direction of the bright, W-shaped constellation Cassiopeia. There you'll find a 4th-magnitude star belonging to the intervening constellation Cepheus. Swing your scope another degree in the same direction and you'll come to the open cluster **NGC 188**, one of the oldest open clusters known in the Galaxy. It's a challenging object for small telescopes, but in a 6- or 8-inch scope at low magnification, NGC 188 appears as a large, circular hazy cloud with a few faint stars across its face. These stars are not true members of the cluster but foreground stars that lie in the same direction as seen from Earth. The brightest members of NGC 188 glow dimly at 12th magnitude.

After you have located NGC 188, turn up the power. High magnification will make the background sky appear darker and increase the separation between stars, bringing out more of the faint cluster members. Also try looking to the side of the cluster to let the stars' dim light fall on the more sensitive part of your retina, a technique called averted vision. Under the best sky conditions, tricks of the trade like this can turn NGC 188 from a fuzzy glow into an impressively rich cluster of faint stars.

A pair of more challenging objects awaits you in the northeastern corner of Cepheus. To locate these two galaxies, start from Polaris again. Head about 3° in a direction somewhat west of the Big Dipper to a 5th-magnitude star. (Figuring out which is east and west near the pole can be confusing. Remember that with your telescope's drive turned off, stars appear to drift from east to west across your eyepiece field.) Just over 1° south of this star lies **NGC 2276**, an Sc-type spiral

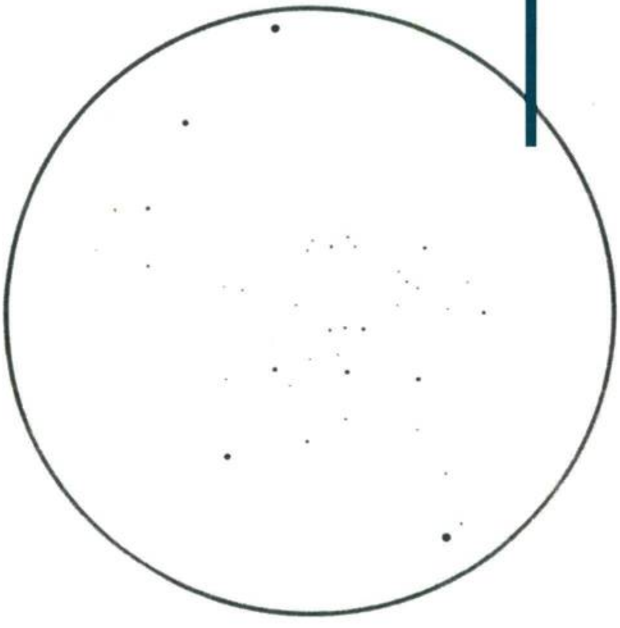


NGC 2336
Mag.: 10.5
Size: 6.9' by 4.0'
U. S. Naval Observatory photo



NGC 2336
Mag.: 10.5
Size: 6.9' by 4.0'
by Chuck Vaughn

NGC 188
Mag.: 8.1
Size: 14'
by Lee T. Macdonald



galaxy that measures 2.6' by 2.5' and glows softly at magnitude 11.4. Seeing NGC 2276 isn't easy, however, because an 8th-magnitude star lies almost directly in front of it. Use high magnification to keep the star and its glare outside the field of view.

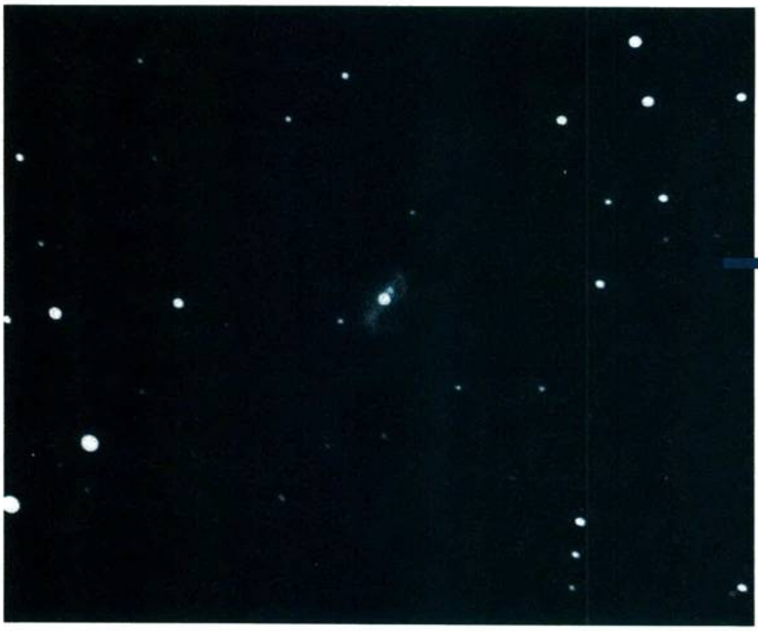
Just 6' east of NGC 2276 lies **NGC 2300**, an elliptical galaxy that appears smaller and considerably brighter than its neighbor. An 8-inch telescope reveals a bright nucleus. Because both galaxies glow around 11th magnitude, you will want at least a 6-inch telescope and a dark sky to see them.

Next swing your scope 5° south of NGC 2276 to a small triangle of 6th- and 7th-magnitude stars in Camelopardalis. Less than 1° south of this triangle lies the 10.5-magnitude spiral galaxy **NGC 2336**. This galaxy appears as a small, somewhat elongated smudge in small telescopes. Long-exposure photographs reveal NGC 2336 as a striking, multiple-arm spiral galaxy.

From NGC 2336 head 3.5° southwest to **NGC 2146**, a spiral galaxy that in the eyepiece looks remarkably similar to NGC 2336. The galaxy's distorted spiral arms place it on the borderline between an Sb-type spiral and an irregular galaxy.

Our next stop is a pair of relatively bright galaxies near the eastern border of Camelopardalis. To find them, begin back at NGC 2336 and locate the 5th-

NGC 2146
Mag.: 10.5
Size: 6.0' by 3.8'
by Kim Zussman

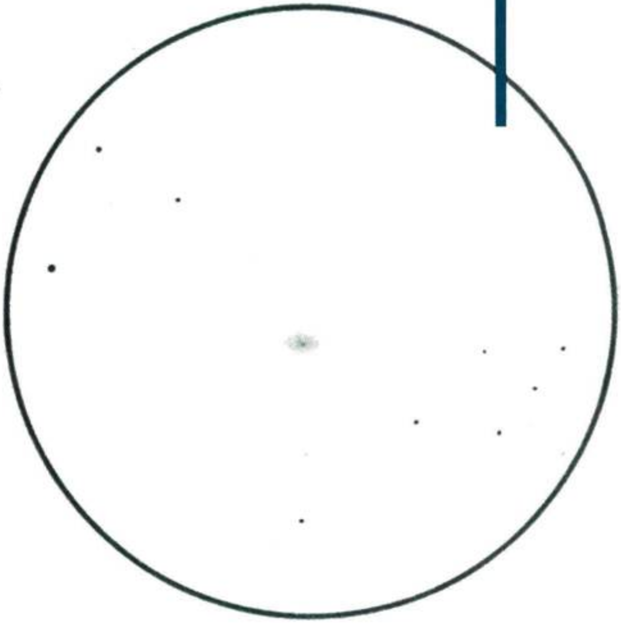


NGC 6217

Mag.: 11.2
Size: 3.1' by 2.7'
by Gene Brings

NGC 6217

Mag.: 11.2
Size: 3.1' by 2.7'
by Lee T. Macdonald



magnitude star about 2° east and 1° south of the galaxy. Extend the line from NGC 2336 to the star another 3° and you'll come to the spiral galaxy **NGC 2655**. Shining at magnitude 10.1 and spanning 5.1' by 4.4', the galaxy is quite easy to see in a 6-inch telescope on a dark night. In an 8-inch scope you may see the galaxy's bright nucleus under good conditions. Less than 1° east of NGC 2655 lies **NGC 2715**, a spiral galaxy that appears considerably smaller, more elongated and, at magnitude 11.4, fainter than its neighbor. You'll probably need an 8-inch telescope to see this galaxy unless your sky is exceptionally dark.

At very high northerly declinations, Camelopardalis stretches east toward the bowl of the Little Dipper. Although this pocket of sky appears sparse to the naked eye, it offers a bright planetary nebula for users of 6-inch or larger telescopes. You can find **IC 3568** most easily by using the 6th-magnitude star that lies about 7° from Polaris and makes a right triangle with Polaris and Delta (δ) Ursae Minoris. The planetary lies 1° south and a little west of this star. With a diameter of only 18" and a magnitude of 11.6, IC 3568 possesses a high surface brightness and shows up well in a small telescope. At low power this planetary looks like a fuzzy star, but at higher magnifications it shows a definite disk. The central star is too faint to spot in most backyard telescopes.

Near the bowl of the Little Dipper lies the spiral galaxy **NGC 6217**. It forms a roughly equilateral triangle with the bowl stars Eta (η) and Zeta (ζ) Ursae Minoris and is flanked by two wide pairs of 6th-magnitude stars located 1.5° apart. The galaxy appears nearly face on and measures 3.1' by 2.7'. The small size gives the 12th-magnitude galaxy a reasonably high surface brightness, making it an easy object for a 6-inch telescope under good conditions. Low magnifications show it as a diffuse elliptical patch, while high power on an 8-inch telescope reveals the small starlike nucleus that is a common feature of Sc-type galaxies.

We began our tour of the far northern sky with the double star Polaris. Now we turn to an equally fine double, **40 and 41 Draconis**. This pair of yellow stars lies 3.5° southeast of Epsilon (ε) Ursae Minoris. Their almost-equal brightness (they shine at magnitudes 5.7 and 6.0) and separation of 19" make this an easy pair for small telescopes or even binoculars that are rock steady.

Two somewhat more challenging double stars in Cepheus complete our journey around the north celestial pole. On the western border of Cepheus lies **Kappa (κ) Cephei**, a pair of 4th- and 8th-magnitude stars separated by 7.4". On nights of good seeing, a small telescope at moderate power splits the pair easily.

Pi (π) Cephei, located 3° southwest of Gamma (γ) Cephei, is a triple star. A 12.0-magnitude star lies 1' from what appears to be an ordinary 4th-magnitude star. But the bright star is itself a double, whose 4.6- and 6.6-magnitude components are separated by just 1.2". You'll need a well-collimated telescope of at least 6 inches aperture, high magnification, and steady seeing to split this difficult double.

Backyard observers often overlook the area surrounding the north celestial pole in favor of better-known regions farther south. To the naked eye, the celestial Arctic appears as a barren region of sky, with Polaris the only bright star. But even a 6-inch telescope reveals a number of deep-sky objects to test your observing skills no matter what season of the year. ☐

Lee T. Macdonald is an avid deep-sky observer living in Newbury, England. His last article for Astronomy *was "Sketching the Deep Sky" (January 1994).*

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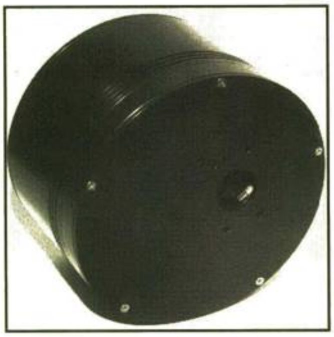

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The 14.5-inch STARSPLITTER

Ready to move up to the bright views of a big-aperture telescope? The new Starsplitter Dobsonians offer a high-quality choice.

by Alan Dyer

Since the late 1970s the Dobsonian reflector has been one of the most popular styles of telescopes for backyard astronomers. This simple but elegant design popularized by John Dobson made it possible for amateurs to break through the aperture barrier and obtain telescopes with unprecedented light-gathering power.

One of the newest entries into the Dobsonian market is the Starsplitter series made by California telescope maker Jim Brunkella. He offers telescopes in apertures from 12.5 to 36 inches, each built using a variation on the classic Dobsonian design popularized by Dave Kriege and several other telescope makers. This clever design uses a lightweight cylindrical upper end that houses the secondary mirror and focuser. The bottom of the scope contains the primary mirror in a box that rides on two semicircular altitude bearings. The large diameter of the bearings and the low center of gravity enable the mirror box assembly to stay short and compact. The final trick for portability is to use aluminum truss tubes to connect the upper end to the base unit. The result is a telescope that breaks apart into manageable components yet assembles into an instrument capable of propelling you deep into the galaxies.

Brunkella's implementation of this Dobsonian design is first class. I test drove a 14.5-inch Starsplitter supplied by Brunkella and found a telescope with superb optics in a beautifully crafted mount.

Setting Up

If you are not familiar with the truss-tube style of Dobsonian, you might think it a complicated and shaky arrangement. Not so. Each night it took only five to ten minutes to assemble the Starsplitter into a solid, easy-to-use instrument.

Before you insert the truss poles (see the photos at right) and clamp on the upper end, however, you first must place the bottom unit of the scope at its appointed spot. The ground board of the 14.5-inch Starsplitter (the part the altitude bearings rest on) weighs 31 pounds. The mirror box (the part with the altitude bearings) weighs 50 pounds without the mirror installed. The 14.5-inch f/5 mirror adds another 22 pounds. You can remove the mirror easily from its cell and carry it separately for safety on road trips.

These components are hefty but light enough for one person to lift in and out of a vehicle. However, to aid in moving the scope any distance, Brunkella supplies each Starsplitter with two 5-foot-long wooden handles that screw onto the sides of the ground board. Once installed, 10-inch rubber wheels on the ends of the handles allow you to lift up the bottom unit of the scope and roll it, wheelbarrow-style, around your observing site or even up and down optional ramps Brunkella offers. The wheeled handles worked well and were a great convenience.

With the handles attached the scope is 33 inches wide, a little too big to fit through most doorways. With the handles removed, the width of the scope is 24.5 inches wide. With the upper end removed and nested on top of the mirror box for transport, the height of the entire stack is 31 inches. The foam-covered truss poles are 50 inches long.

The upper and lower wooden clamps held the truss poles rigidly. Assembly required no tools or fiddling with loose nuts and bolts. The Starsplitter needed an initial collimation after arrival, but each night after that the scope went together so consistently that it called for little, if any, touchup on the collimation.

Collimating the primary mirror required no screwdrivers or wrenches. Three large hand knobs at the back of the metal mirror cell perform the necessary tilt adjustments. The knobs were easy to turn yet stayed put under normal use.

The secondary mirror is mounted in a holder and spider made by Kenneth Novak. The secondary also has collimation screws (these require a screwdriver) but they are set-and-forget adjustments — day-to-day col-

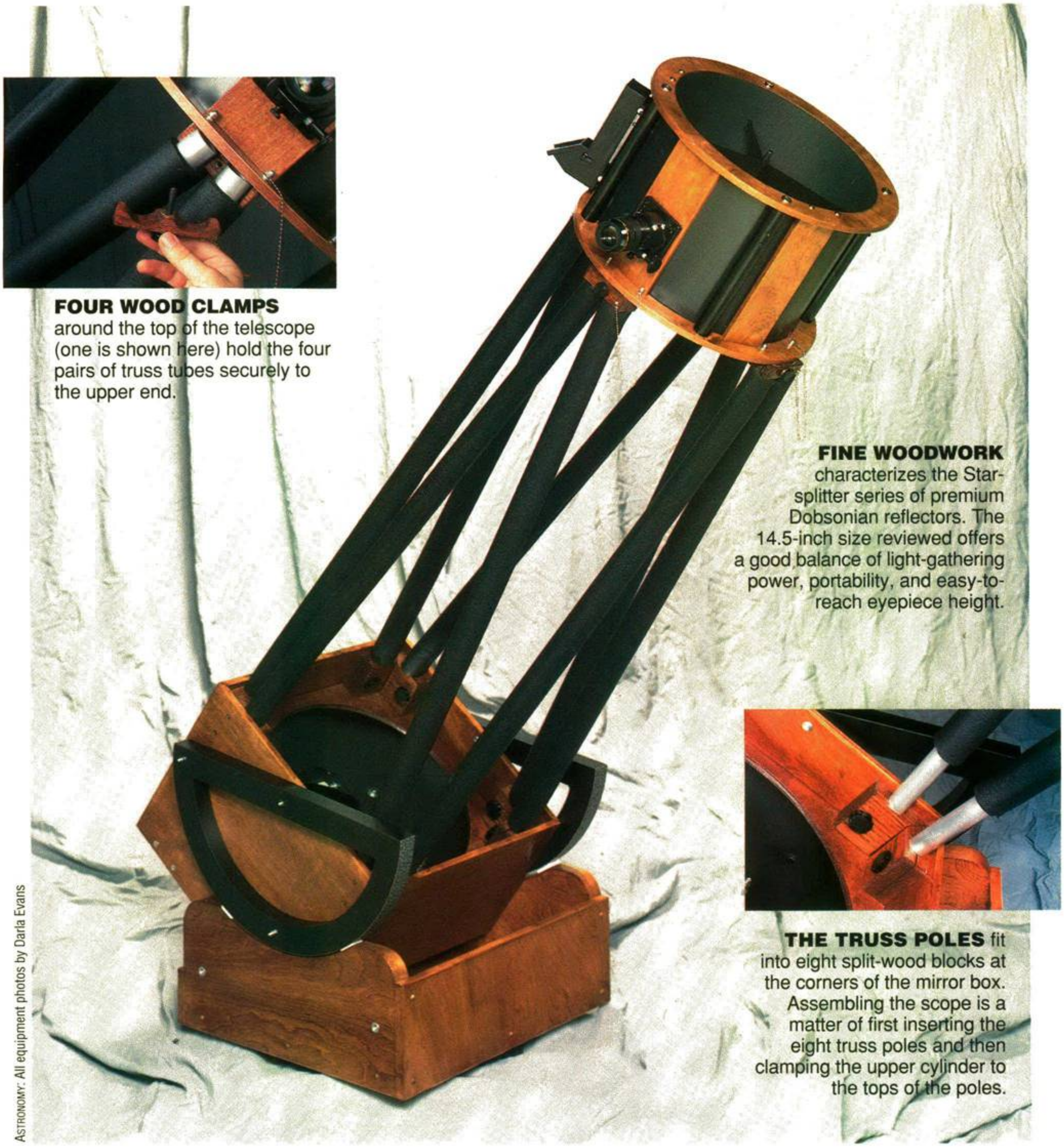
Standard Specifications

Optics manufacturer	Galaxy Optics
Focal ratio	f/5
Secondary size (minor axis)	2.6 inches
Secondary obstruction (by diameter)	18%
Size of focuser	2 inches
Total telescope weight	90 lbs.
Weight of heaviest component	50 lbs.
Eyepiece height at zenith	75 inches
Manufacturer-direct price	$2,795
Promised delivery time	12 to 16 weeks

Optional accessories

Enhanced (94%) primary coating	$200
Nylon light shield	$80
Rear dust cover	$35
Tectron collimation tools	$100
Dew shield/front baffle	$50
Electronic dew guard for secondary	$100
Switch for fan	$50
Loading/unloading ramps	$95

Starsplitter Telescopes, 3228 Rikkard Drive, Thousand Oaks,
CA 91362, (805) 493-2489.



FOUR WOOD CLAMPS around the top of the telescope (one is shown here) hold the four pairs of truss tubes securely to the upper end.

FINE WOODWORK characterizes the Starsplitter series of premium Dobsonian reflectors. The 14.5-inch size reviewed offers a good balance of light-gathering power, portability, and easy-to-reach eyepiece height.

THE TRUSS POLES fit into eight split-wood blocks at the corners of the mirror box. Assembling the scope is a matter of first inserting the eight truss poles and then clamping the upper cylinder to the tops of the poles.

ASTRONOMY: All equipment photos by Darla Evans

limation is done by tweaking the primary mirror.

For our test scope, I did have to install and adjust the secondary mirror holder. Although the scope left California with the secondary in place and aligned, during shipment the holder worked loose from the spider and arrived lying in the wood shipping crate.

The Starsplitter comes with a thorough booklet by Tippy D'Auria and Vic Menard on how to collimate a telescope. The booklet explains the use of a set of three collimation eyepieces that I would heartily recommend for this or any Dobsonian telescope. Brunkella offers these as a $100 option.

Using the Starsplitter

The 14.5-inch Starsplitter is a friendly size of telescope. For me, reaching the finder and eyepiece required no ladder when the telescope was aimed below 45° or so and only one step up a short ladder when the scope was aimed high in the sky.

Starsplitters come with a Telrad finder, an excellent sighting device, as standard equipment. With the upper end installed so the focuser was on the right side of the telescope (as seen from the rear of the scope), the Telrad ended up above the focuser near the top of the tube. In this position I found the Telrad finder a little awkward to look through for short, right-eye-dominant observers like me. Installing the upper end with the focuser on the left, placing the Telrad on the lower side of the scope, proved to be more convenient.

Our test scope came with a fine-quality focuser made by Jim's Mobile, their NGF-3 model. This is a Crayford-style unit with a focusing tube that rides on a roller bearing. The focuser

CHECKING THE OPTICS

Telescope companies often advertise their mirrors as having a certain accuracy as measured in fractions of a wavelength of light. The smaller the fraction, the closer the mirror is to perfection. The problem with interpreting these figures is that there has been no standard for stating these numbers. Was company A's 1/4-wave figure measured the same way as company B's 1/8-wave?

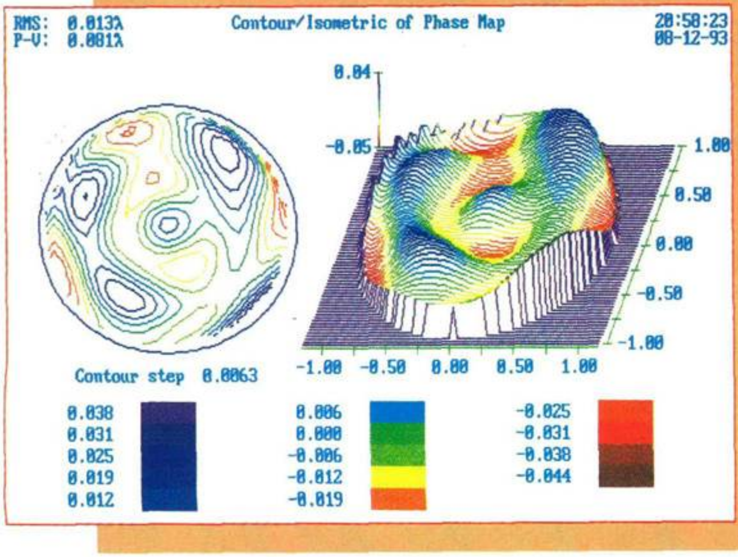
Galaxy Optics, the supplier of the mirrors for Starsplitter telescopes, promises to meet certain wavefront error figures *and* states how those numbers are measured. Galaxy promises that each of its primary mirrors, at least units under 20 inches, has a surface accuracy of 1/8-wave peak-to-valley or better. This means that the deviation of the mirror's surface from the ideal shape is no more than 1/8 of a wavelength of light. Galaxy Optics uses red light (the 632.8 nanometer line from a helium-neon laser) as a standard.

When light hits a mirror and reflects, any error in the surface produces double the error in the wavefront of the light leaving the mirror. A mirror with a 1/8-wave surface produces a reflected wavefront with an error of 1/4 wave. If a mirror can produce a 1/4-wave reflected wavefront it is by definition considered to meet "Rayleigh's criterion" and to therefore be "diffraction limited."

But Galaxy also states two other specs not often seen in amateur astronomy literature — the RMS surface error and the Strehl ratio. The RMS (root-mean-square) figure is a measure of how smooth the surface is. A mirror with a 1/8-wave bump that occupies only a small part of the surface will provide better images than a mirror peppered with 1/8-wave bumps and pits all over its surface will provide. The RMS figure is a statistical average of how many unwanted peaks and valleys there are. Galaxy promises that each of its mirrors will be at least 1/40-wave RMS.

To understand the Strehl ratio, remember that at high power a star appears not as a point but as a tiny disk of light (the Airy disk) surrounded by one or more faint diffraction rings. In a perfect telescope, 84 percent of the light is focused into the Airy disk, the rest into the rings. A mirror with a Strehl of 1.00 focuses the maximum amount of light (84 percent) into the Airy disk. A mirror with a Strehl of 0.9 focuses 75 percent (84 x 0.9) of the incoming light into the Airy disk. A telescope with a 1/4-wave error on the wavefront (i.e. diffraction limited) will focus 68 percent into the Airy disk. This translates to a Strehl ratio of 0.8. Galaxy promises at least 0.8, with 0.9 typical.

A LASER INTERFEROGRAM provides an accurate map of the errors in the surface of a lens or mirror. This is the interferogram produced by Galaxy Optics and supplied with the 14.5-inch primary mirror in our test scope. In such plots, the magnitude of the surface errors is greatly exaggerated for clarity.



Galaxy checks these figures by means of a laser interferometer, a device that can create a contour map of the mirror's surface. For a surcharge, a customer can have his or her mirror supplied with an interferogram (a printed contour map) as documentation of its quality.

The primary mirror in the Starsplitter scope we reviewed came with documentation stating its peak-to-valley surface error was 0.081, about 1/12 wave. The RMS value was a claimed 0.013, about 1/75 wave, while the stated Strehl ratio was 0.993. These figures came from measuring the mirror at nearly 3,000 points on its surface. The flat secondary mirror also came with an interferogram stating its peak-to-valley figure as 0.047 (1/21 wave) with an RMS of 0.005 (1/200 wave), measured at more than 2,400 points.

These are impressive figures. Could we confirm them? After checking with half a dozen independent optical labs around the country, we could find no one set up to analyze a mirror as large as this 14.5-inch f/5. Without the aid of laser interferometry, we were left with the tried and true star tests for checking the optics.

During moments of better seeing, 4th- and 5th-magnitude stars showed tiny, sharply defined Airy disks surrounded by a first diffraction ring. Bright stars inevitably showed the fuzzing effects of the average seeing that plagued our test nights. Out of focus, however, bright stars showed well-defined and nearly identical diffraction patterns on either side of focus, a sign the mirror was not under or overcorrected. The only difference was that the diffraction ring about 70 percent of the way from the center to the edge appeared slightly darker than the rest of the pattern when the image was outside of focus. Inside of focus, this same zone appeared slightly brighter than the rest of the pattern. As for astigmatism in the primary or secondary, there was none — diffraction patterns were perfectly circular. As another check, a 100-line-per-inch Ronchi grating placed at the focus with three lines visible showed dead straight lines (any curvature is a sign of major figuring errors).

The minor zonal error picked up in the star test may well be from the 1/12-wave bumps shown in the interferogram. If so, this is a testament to the astonishing sensitivity of the star test for detecting mirror errors — but not in a way you can quantify and easily document. The fact that the effect of this tiny surface error was even visible is evidence for the critical smoothness of the optics. If the mirrors had been rough, the effects of the bumpy surfaces would have masked such a slight zonal error.

In all, the performance of the Galaxy Optics mirrors was excellent. While we were unable to confirm Galaxy's numbers, there was nothing about the mirrors' real-world performance to suggest that Galaxy Optics had not supplied exactly what it had promised — a diffraction-limited set of optics with ultra-smooth surfaces.

action was smooth and precise and exhibited no image shift. It had 1¾ inches of travel. The tension was sufficient to prevent heavy eyepieces from sliding out of focus. My only criticism is that the set screws that hold the eyepiece are small, making it hard to adjust them with gloves on.

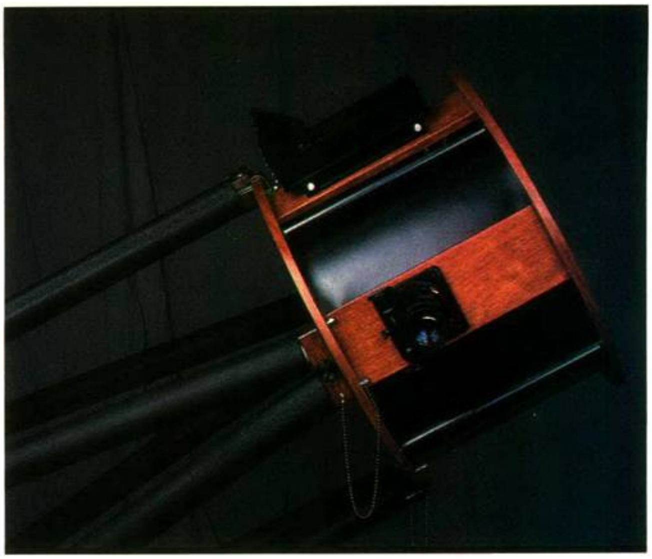
On nights with near-freezing temperatures, I found the Starsplitter's 2-inch thick mirror took about an hour to cool down. This is fairly standard for this type of telescope. The mirror cell is mounted in an open framework to promote air circulation. As an additional aid, a battery-operated fan located in the center of the mirror cell blows air against the back of the mirror. However, I found that on cold nights (the nights you most need to use the fan) the little 9-volt battery soon died.

As with all truss-tube telescopes, some sort of fabric cover for the tube is a required accessory. Without a cover in place I found glare from nearby lights could shine directly into the eyepiece and flood the field. The open mirror cell, while nice for cooling, also allows light reflected off the ground to enter the tube from below. Two essential options, a Nylon tube cover and a rear dust cover, eliminate both sources of stray light and boost contrast.

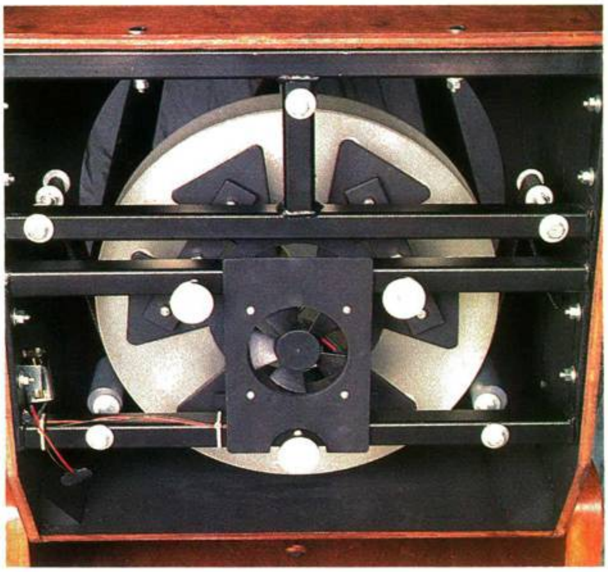
Brunkella has used the now-standard Dobsonian construction materials, Ebony star Formica riding on Teflon pads, for his bearing surfaces. The result was wonderfully smooth motions in both axes with the right amount of stiction to keep the scope in place yet make it easy to nudge the scope to center objects. On windy nights, the telescope was susceptible to being blown off-target, but that's an unavoidable characteristic of big Dobsonians.

The scope was well-balanced for use with normal-weight eyepieces over most of the sky. When aimed low the scope was a little top heavy and tended to sink easily even with a regular 26mm Plössl eyepiece attached. Brunkella supplies a machined counterweight that screws easily onto the top of the mirror box. This rebalanced the scope for low-angle viewing with most eyepieces. The scope was still top heavy, however, with massive eyepieces such as 35mm Panoptic. Users can order Starsplitters with additional weights inside the mirror box.

Like most Dobsonians, the telescope was well-damped. Vibrations from a rap to the top end died out in 1½ to 2 seconds. Gusts on a couple of very windy test nights did jostle the image around, making it difficult to do any high-power planetary viewing. But on calm evenings the Starsplitter performed well both as a deep-sky "light bucket" and as a high-resolution planetary telescope.



THE UPPER END houses a smooth-operating focuser made by Jim's Mobile (the NGF-3 model) and a Telrad finderscope. Total weight of the upper end with finder is 10 pounds. For the 14.5-inch scope tested, lifting the upper end onto the truss tubes does not require a ladder.



THE MIRROR CELL is an open framework that suspends the mirror on its edge by means of a strap. The back of the mirror rests on an 18-point flotation system. A battery-operated fan aids in cooling the mirror. The three white knobs near the central fan are for collimating the mirror.

Good Looks

The Starsplitters are solidly constructed of veneered plywood. Buyers can select fom mahogany, oak, or birch construction. For maximum durability the wood clamps are made of oak. All wooden components are stained and polyurethane coated to a lustrous finish. The result is a telescope that is as good to look at as it is to look through. And on several nights I dispensed with the optical testing and did just that — simply looked. The views a telescope of this size and quality can provide are nothing short of amazing.

When the seeing settled in, Saturn's rings showed distinct color variations. The dusky Crepe ring around the inside edge of the rings was obvious. The Andromeda Galaxy's two dust lanes were plainly visible, and Andromeda's companion galaxies looked as big and bright as Andromeda itself does through smaller scopes. The bright galaxy NGC 7331 in Pegasus was surrounded by several of its 15th-magnitude companion galaxies, while nearby, the Stephan's Quintet cluster of galaxies was easy to pick out. With an OIII nebula filter in place, the Veil Nebula was an astonishing wreath of braided nebulosity.

And on it went. Object after object fell prey to the Starsplitter's fine optics and generous light-gathering power. If you're after this type of eye-opening observing experience, the Starsplitter Dobsonians are certainly worth consideration. ☐

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8x50mm—2.7x light grasp of 30mm models. Bright 6.25mm exit pupil. #7090 (white) #7094 (black) ***$ call***

8x50mm Illuminated—Wireless illuminator with adjustable brightness. #7092 (white) #7096 (black) ***$ call***

9x60mm — 44% more light grasp than 50mm models. #7091 (white) #7095 (black) ***$ call***

9x60mm Illuminated—Wireless illuminator with adjustable brightness. #7093 (white) #7097 (black) ***$ call***

Mounting Brackets - Unique sliding dovetail design. Super high quality. Fits any scope 6" and over including Celestron & Meade SCs.

8x50mm bracket #5040 ***$ call***
9x60mm bracket #5041 ***$ call***

Rack-and-Pinion Focusers

Finest in their class. Diagonal-cut plated brass racks, oversized knurled knobs, long focus travel.

1.25" #13007 ***$ call***

2.0" includes 1.25" adapter. #13003 ***$ call***

NEW! Low-Profile Focusers

Perfect for fast optical systems. Ideal replacements for "Odyssey" scopes.

1.25"-#13014 ***$ call***
2.0" - #13016 ***$ call***

Night Vision Flashlights

An essential accessory for astronomers. Choose from our wide selection.

Astronomer's Flashlight #5701 ***$ call***
Nitewriter Pen #5709 ***$ call***
Hands-Free Flex Light #5707 ***$ call***
Starlite LED Flashlight #5714 ***$ call***
Celestron LED Flashlight #5720 ***$ call***

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Standard Model—Adjustable height center column and padded seat. #5935 ***$ call***

Deluxe Model—Built for professional musicians. Extra heavy duty. #5934 ***$ call***

Accessories See Our Catalog for Even More!

45° Erect Image Diagonal Prisms

See the world as it really is with Orion's 45° erect image diagonal. Ideal for all refractors and compound telescopes used for terrestrial viewing.

1.25" Diagonal #8790
.965" Diagonal #8791
Hybrid 1.25"/.965" Diagonal #8792

$ call

90° Star Diagonal Prisms

Orion's multi-coated diagonals let you view at a right angle from the direction your telescope is pointing. The image is backward. Ideal for refractors and Schmidt-Cassegrains used for astronomical viewing.

1.25" Star Diagonal #8763 **$ call**
Hybrid 1.25"/.965" Star Diagonal #14008 **$ call**
.965" Star Diagonal #8761 **$ call**

2" Prism/Mirror Diagonals

2" Prism Diagonal–Absolutely the finest quality multi-coated 2" prism for highest light transmission.

For refractors #8770
For Schmidt-Cass. #8771

$ call

2" Mirror Diagonal– Affordable, high-quality star diagonal.

For refractors #8773
For Schmidt-Cass. #8772 **$ call**

Universal Camera Adapters

For prime focus or eyepiece projection astrophotography.

.965" #5268 **$ call**
1.25" #5264 **$ call**
Hybrid 1.25"/.965" #8782 **$ call**

Variable Power Camera Adapter

Allows variable projection distances during eyepiece projection photography. For 1.25" eyepiece holders.

#5262 **$ call**

Tele-Extenders

For high powered photography with your Meade, Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.

Standard Tele-Extender #5125 **$ call**
Variable Tele-Extender #5127 **$ call**

T-Adapters

Threads to rear cell of telescope, requires t-ring for your camera model.

for SC #5116 **$ call**
for C-90 #7115 **$ call**

T-Rings

Available for many different camera types, call toll-free or see our catalog for your particular model.

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Allows easy, accurate, ultra-sharp focusing, essential for astrophotography.

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Bogen/Velbon/more!
Huge selection of tripods available, for telescopes, spotting scopes and giant binoculars. Choose from assembled models or mix-and-match pan heads and tripods, sold separately. See our catalog for details.

Orion Slow Motion Adapter

Attaches to your photo tripod pan head. 2 slow motion control knobs to make precision adjustments in altitude and altazimuth. Very handy for tracking planets, the Moon, etc. with refractor telescopes and small spotting scopes. Attaches with a standard 1/4-20 thread.

#7012 **$ call**

Extension Cable for Slow Motion Control

12 3/4" flexible cable, for tracking at high powers. Buy 2, one for each axis.

#5014 **$ call**

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For comfortable two-eyes-open observing. You won't believe the views! Threads securely to the rear cell of your telescope. Requires two identical eyepieces.

#9720 **$ call**

f/6.3 Reducer/Corrector

Get f/6.3 performance from your f/10 Schmidt-Cassegrain.

#5120 **$ call**

NEW Model 3 Sky Wizard™

Electronic Finder & Sky Catalog

Let Sky Wizard do the work, while you relax and have fun observing!

- Find any celestial subject in 15 seconds!
- One minute setup — no polar alignment or levelling.
- Observe hundreds of objects in a few hours!
- For ANY telescope, with or without a motor drive. *Even altazimuth or Dobsonian scopes!*
- Digital display of celestial coordinates (RA & Dec).
- Built-in electronic sky catalog — find subjects by their common catalog name, not their coordinates. Complete with object descriptions.
- Powered by a single 9v battery. Weighs just 6 oz!

Complete system requires Sky Wizard Model 1 or 2 and a telescope installation package, sold separately.

Encoders and cables available separately for custom installations. Call for details.

Sky Wizard Model 1
Includes the Messier Deep Space Catalog of 110 objects, 28 bright stars, and the planets.

#7801 **$ call**

Sky Wizard Model 2
Huge 2100+ object database, plus a user catalog to store 27 objects of your choice.

#7802 **$ call**

Sky Wizard Model 3
Gigantic 10,000 object database, expanded subject descriptions, RS-232 port.

#7803 **$ call**

Installation Packages
Includes 2 encoders, all required mounting hardware and brackets, connecting cables, and complete illustrated instructions.

Celestron Super Polaris	#27100	**$ call**
Celestron Ultima 8" & 11"	#27101	**$ call**
Celestron Great Polaris	#10303	**$ call**
Celestron C-5	#10304	**$ call**
Celestron G-11	#10305	**$ call**
Celestron Classic 8" & Powerstar 8"	#27102	**$ call**
Meade 8" & 10"	#27103	**$ call**

Dobsonian (fits Coulter and most others)
Call for stock # for your model **$ call**

Installation packages available for other telescopes.

Orion Off-Axis Guider

Allows you to observe a guide star during photography. Multi-coated.

#5144 **$ call**

Orion UltraGuider

Wide-range lateral prism adjustment; precision helical focusing; adjustable camera focal plane position.

#5139 **$ call**

110v Motor Drive for Refractors

Fits Orion equatorial mounts, many others. Plugs into any standard AC outlet.

#17001 **$ call**

12 Amp Hour Porta Pac Battery

Ideal for high power-consuming accessories. With carrying case. Weighs only 10 lbs.

#2354 **$ call**

Filters

Glass Solar Filters

High-quality optical glass filters, for superb images of the sun with your telescope. Triple-coated with advanced scratch-resistant stainless steel alloy. Great for both visual and photographic use. Slide fits over the front of your telescope.

For 8" SCs #7713 **$ call**
For 10" SCs #7715 **$ call**

***NEW!** Solar glass filters for Deep Space Explorer reflectors. Many other sizes available—see our free catalog for details.*

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

.965" #5664, 1.25" #5662 **$ call**

Color Eyepiece Filters

Highest quality precision-ground optical glass. Fully anti-reflective coated. Solar system observations are dramatically improved. Thread into the barrel of any standard eyepiece, or directly into a universal camera adapter.

.965" Basic Set of 4 Filters #80A Blue, #58 Green, #25 Red, #15 Yellow.
#5510 **$ call**

1.25" Basic Set of 4 *#80A Blue, #58 Green, #25 Red, #15 Yellow.* #5514
1.25" Expansion Set of 4 *#21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.* #5516
1.25" Advanced Set of 4 *#8 Light Yellow, #23A Light Red, #38A Deep Blue, #56 Light Green.* #5570
$ call

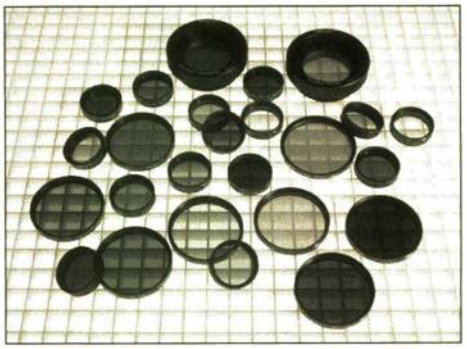
Deluxe Set of 8 Filters for 1.25" Includes all the filters in our basic and expansion filter sets.
#5517 **$ call**

Full Set of 12 Filters for 1.25" Includes Basic Set, Expansion Set, Advanced Set.
#5575 **$ call**

2" Set of 4 Includes #80A Blue, #58 Green, #21 Orange and #12 Yellow.
#5513 **$ call**

Individual .965", 1.25" & 2" Filters- Many colors available, see our catalog for details.

SkyGlow™ Light Pollution Filters



Enhance your viewing of faint deep sky objects with the best broadband light pollution filter you can buy. Our SkyGlow absorbs frequencies emitted by city lights, allowing transmission of the rest of the visible spectrum, yielding dramatic results.

SkyGlow Broadband Filters—Photographic and Visual
For use in slight to moderately light polluted areas.

1.25" Broadband Filter–fits 1.25" eyepieces. #5660 **$ call**

SC Broadband Filter–fits rear cell of Meade & Celestron SC scopes. #5658 **$ call**

52mm Broadband Filter–For 52mm camera lenses, (Adapter rings available for other diameters.) #5668 **$ call**

2.0" Broadband Filter–fits 2" eyepieces. #5659 **$ call**

.965" Broadband Filter–fits .965" eyepieces. #5661 **$ call**

SkyGlow UltraBlock Filters–Visual Only
For severely light polluted areas and faint nebulae.

1.25" UltraBlock Filter–fits 1.25" eyepieces. #5654 **$ call**

SC UltraBlock Filter–fits rear cell of Meade & Celestron SC scopes. #5656 **$ call**

Eyepieces & Barlows

NEW! 40mm Sirius Plossl! See catalog for details.

✧ Sirius™ Plössl 1.25" Eyepieces

Fantastic Name-Brand Quality Eyepieces at an Incredible Low Price!

You could pay nearly twice the price for 'famous name' Plössl eyepieces, but we don't think you'll be able to tell the difference if you compare them to these fantastic eyepieces!

Sirius Plössls are top-quality, 50° apparent field eyepieces with extremely sharp images of impressively high contrast. Ideal for all types of reflector, refractor and catadioptric telescopes. The Plössl design is renowned for its fantastic performance and has in recent years become the standard by which all other eyepieces are compared.

Each eyepiece is of the classic 4-element Plössl design. Every air-to-glass surface is fully Magnesium Fluoride anti-reflection coated. All lens edges are blackened in the same way as expensive military optics, to further eliminate any scattering of stray light and to maximize contrast.

The optics are mounted in precision black anodized aluminum housings with chrome-plated brass 1.25" barrels for durability and precision fit.

We guarantee you'll be impressed with the performance of the Sirius Plössls, even when compared to the more expensive name-brand Plössls.

25mm #8530, *17mm* #8531, *10mm* #8532, *7.5mm* #8533 **$ call**

Call for information on special package deals!

Any 2 *$ call*
Any 3 *$ call*
All 4 *$ call*

Case only #5911 **$ call**

Explorer .965" & 1.25" Eyepieces

These fine quality multi-coated eyepieces offer great performance at Orion's low direct-discount price. Three different optical designs are incorporated, to maximize efficiency in the various focal lengths. Black anodized, internally blackened, threaded for filters (except 40mm .965").

.965 Orthoscopic
5mm #8580, **7mm** #8581, **9mm** #8582, **12.5mm** #8583 **$ call**

.965 Kellner
18mm #8584, **25mm** #8585 **$ call**

.965 Achromatic Huygenian
40mm #8586 **$ call**

1.25" Orthoscopic
5mm #8500, **7mm** #8502, **9mm** #8504, **12.5mm** #8506, **18mm** #8524, **25mm** #8526 **$ call**

1.25" Kellner
6mm #8536, **9mm** #8538, **12mm** #8540, **18mm** #8508, **25mm** #8510, **40mm** #8512 **$ call**

Superb Ultrascopic™ Eyepieces

Unlike other premium eyepieces, Orion Ultrascopics offer complete multi-layer coatings on ALL surfaces, for superior light transmission and contrast. Modern 5- and 7- element designs for pinpoint star images and breathtaking detail. Wide 52° field of view. Guaranteed to beat other brands selling for much more! Unsurpassed high-performance design!

Medium-High Power 5-element
20mm #8566, **15mm** #8568, **10mm** #8570, **7.5mm** #8572 **$ call**

Wide Field 5-element
25mm #8564 **$ call**
30mm #8562 **$ call**
35mm #8560 **$ call**

***High Power 7-element** —Long Eye Relief*
5mm #8574, **3.8mm** #8576 **$ call**

MegaVista 1.25" & 2" Eyepieces

These outstanding eyepieces feature a 7-element design and incredibly sharp, fully multi-coated optics. The long eye relief and integral rubber eyeguards make these ideal for eyeglass wearers. The extra wide field of view (67°-70°) provides stunning images, perfect for deep space observing.

10.5mm 1.25" #8552 **$ call**
16.8mm 1.25" #8554 **$ call**
34mm 2" #8587 **$ call**
40mm 2" #8588 **$ call**

Illuminated Reticle Eyepieces

Orion offers 4 versions of the illuminated reticle eyepiece, a necessity for long exposure astrophotography and very useful for polar alignment. All have 1.25" barrels.

12.5mm Plossl Illuminated Reticle
Illuminator has fully adjustable brightness. Features double crossline reticle. Batteries included.
#8484 **$ call**

12mm Kellner Illuminated Reticle
Features double crossline reticle and red LED illuminator. Plugs into power panel drive bases.
#8482 **$ call**

9mm Orthoscopic Illuminated Reticle
Adjustable brightness illuminator. 'Bull's-eye within crosshairs' reticle. Needs 2 SR-44 batteries, not included.
#8488 **$ call**

12mm Kellner Illuminated Reticle
Same as 8482 above except has a wireless illuminator. Needs 2 SR-44 batteries, not included.
#8481 **$ call**

SR-44 Batteries #2360 **$ call**

UltraZoom™ 7–21mm

The finest zoom you can buy for your 1.25" telescope. For astronomy or terrestrial observing. 65°-35° field. Fully coated.

#8556 **$ call**

See our free catalog for a fantastic selection of name-brand eyepieces!

CELESTRON Tele Vue

Barlow Lenses

Orion offers a large selection of barlow lenses, allowing you to double or even triple the power of your eyepieces, maximizing the versatility of your collection. Available in .965", 1.25" and 2" diameters.

Fully Baffled 2x Barlow
Multi-coated, with internal baffling to block transmission of stray light. Premium performance at a remarkable price.

.965" #8740 **$ call**
1.25" #8746 **$ call**
2" #8724 **$ call**

Ultrascopic 2x Fully Multi-Coated Barlow
3-element Ultrascopic lens for superior images and precise color correction. Fully multi-coated optics, black anodized barrel. 1.25 barrel.
#8750 **$ call**

VariPower 2-3x Barlow
Allows you to adjust the magnification factor of the barlow by sliding the internal cell along a calibrated scale. Fully multi-coated optics. 1.25" barrel.
#8748 **$ call**

Shorty Barlows
The short bodies allow extra versatility: provides 2x magnification when the eyepiece is inserted directly, and 3x magnification when positioned before the diagonal on a refractor or SC. Will work in all telescopes, including those where longer barlows won't work.

.965" #8710 **$ call**
1.25" #8711 **$ call**

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Glorious Visions

At night the sky comes alive with light and color. Camera and film capture the beauty of its star trails and dusky sunsets and the zodiacal light.

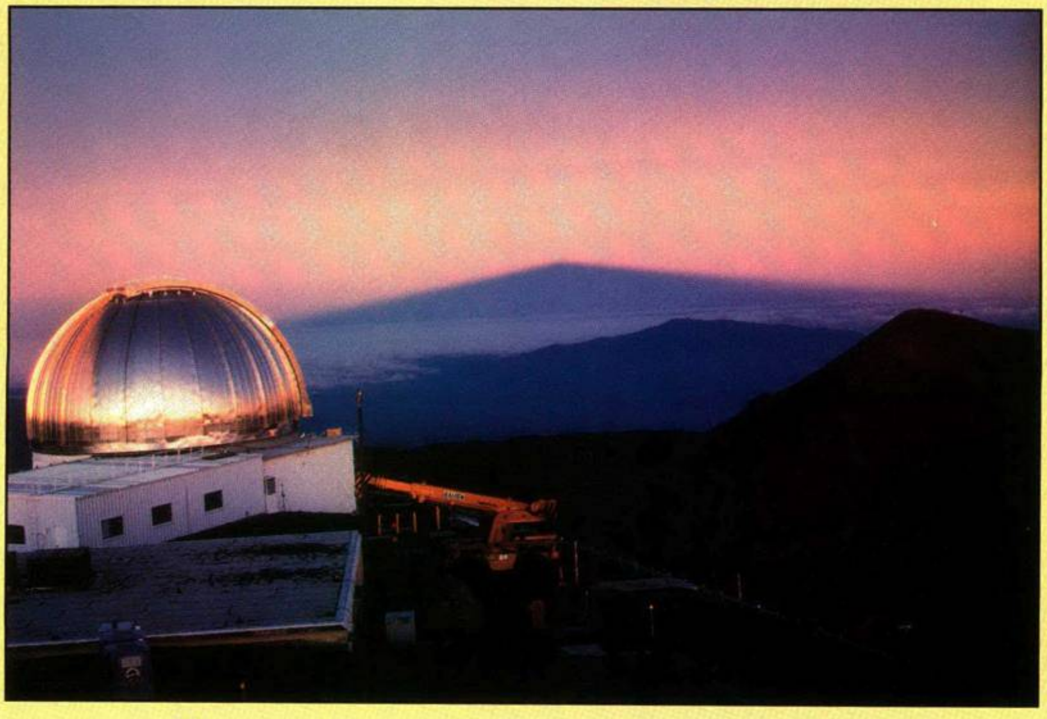
Story and photos by William C. Livingston

A glance at the night sky shows a meeting place of Earth and stars. Each night photons wash over the sky after a long journey from a star or a galaxy. Some crash into the sea of molecules that forms Earth's atmosphere. Others, distorted slightly by our cocoon of gases, pass through the atmosphere and strike Earth's surface every clear night.

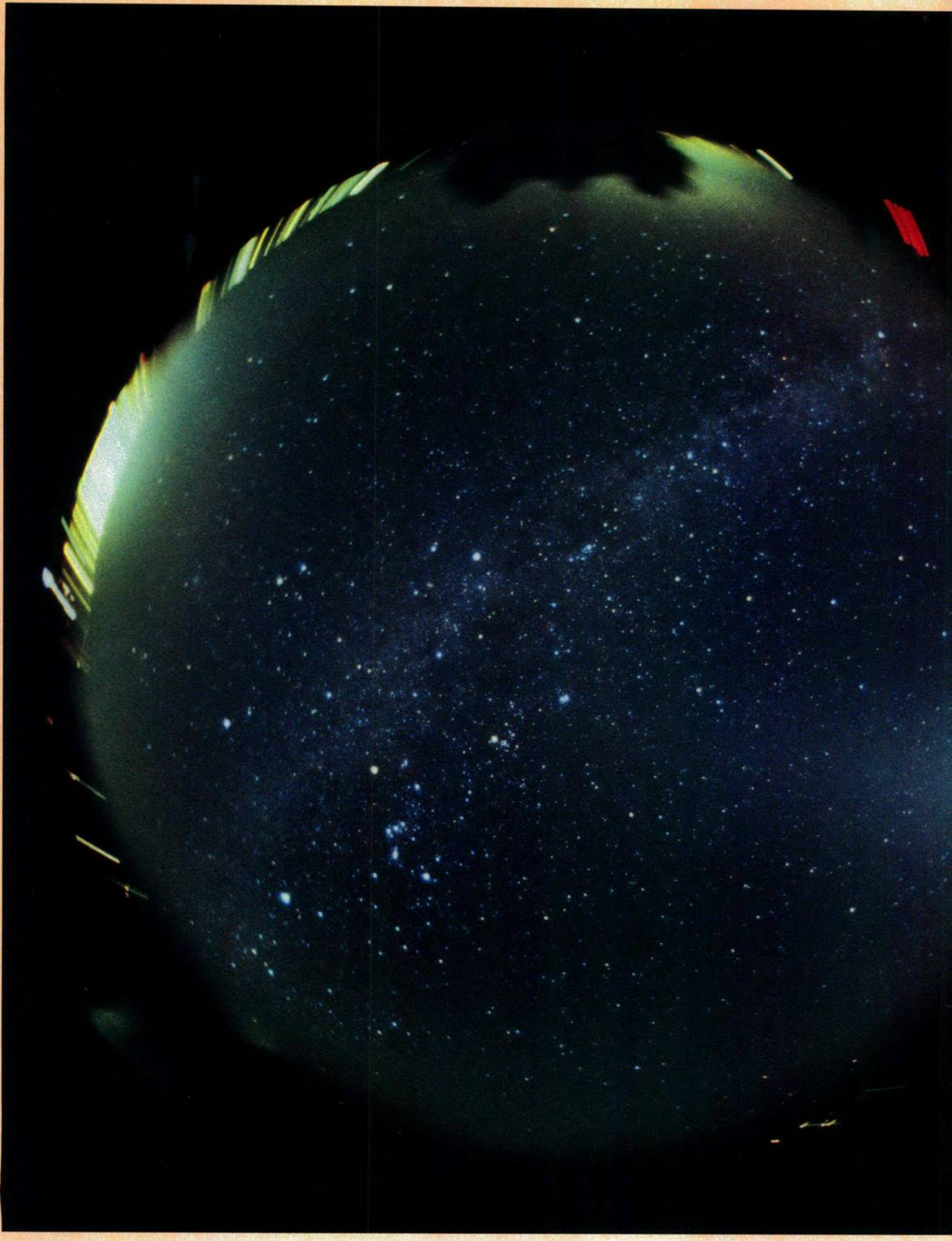
It's surprisingly easy to capture this on film — the ruddy glow of a twilight, the multicolored arcs of stars as they trail across the sky, the shadow of a mountain as it crawls across a valley up onto the pinkish skyglow behind. Four basic types of glorious visions paint the sky in a progression from the deep blackness of night to the stark brilliance of day: star colors, subtle nighttime glows, sunrise and sunset, and daytime cloud phenomena.

Earth's rotation provides the most beautiful and inviting type of glorious vision, star trails. To capture them, load your camera with color film, travel to a dark-sky site, set the camera on a tripod, and open the shutter for an hour, maybe two,

Bathed in a ruddy glow, the dome of the 3.6-meter Canada-France-Hawaii telescope sits atop Mauna Kea, Hawaii. The reddish dusk was caused by sunlight refracting off dust particles suspended in the atmosphere from Mt. Pinatubo's eruption.

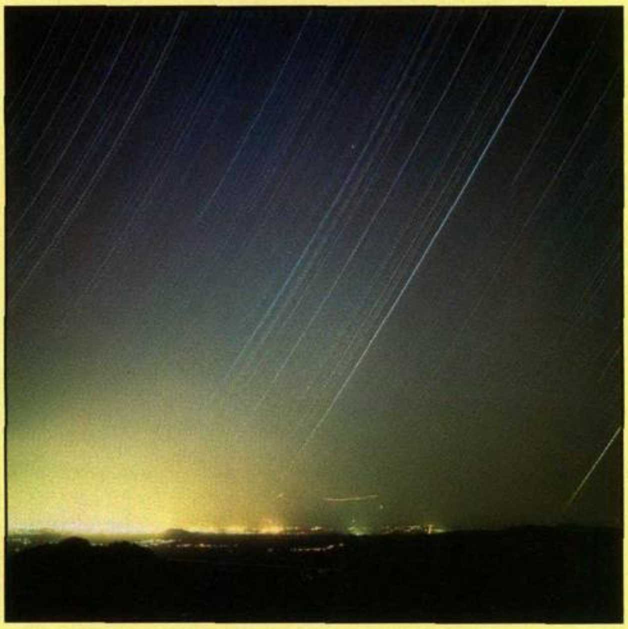


Stretching miles across a valley, the shadow of a mountain paints the landscape as the Sun sets in back of the photographer. The shadow, projected onto a pinkish skyglow, appears strikingly black.



The brilliant pinpoints of stars and the diffuse band of the Milky Way together make ordinary light and color in the night sky. But a long-exposure image also shows the faint glow of the zodiacal light (right) and the menacing green-yellow glow of light pollution on the horizon at left. Photo by Dean Kitelson.

Like a giant bird rising over the mountain, a slowly undulating orographic cloud hovers over the McMath Solar Telescope on Kitt Peak.

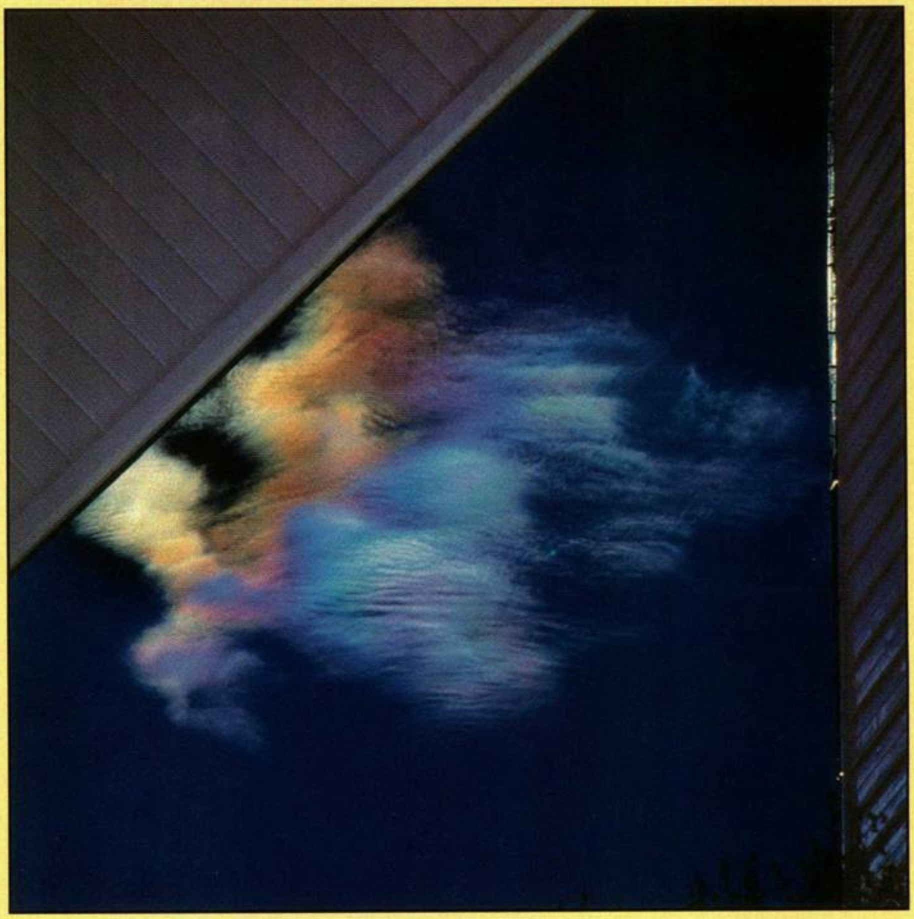


Will light kill astronomy? Although white, yellow, blue, and orange stars slowly rise out of the morning glow of Tucson, artificial light pollution leaks into the sky around the horizon.

maybe three. You'll come away with a beautiful portrait of the stars in all their many-colored glory streaked across the sky.

Stars are not the only messengers of light in the night sky, however. The *brightest beacon, the Sun, produces glows that are visible even after it sinks below* the horizon. The zodiacal light is a diffuse band of light produced by sunlight that scatters off small particles in the disk of the solar system. To see it, look along the ecliptic — the apparent path of the planets in the sky —in the west after sunset

The sky is alive with natural glows. This airglow and sky glow is produced by light scattered throughout the solar system, chiefly by sunlight reflected from the Moon and particles near Earth.



A rainbow of colors refracts through an altocumulus cloud seen through the towers of the McMath Solar Telescope. Because sunlight passes through the cloud and refracts through ice crystals of uniform size, observers see iridescent colors.

and in the east before sunrise. A part of the zodiacal light, the *gegenschein* (or counterglow), appears as a faint glow opposite the Sun's position in the sky.

Sunsets and sunrises produce striking skyglows. Anyone who witnessed a sunset after the eruption of Mount Pinatubo in June 1991 can recall the rich red glows routinely visible. The volcanic ash suspended in Earth's atmosphere acted as a filter for sunlight as well as a cloud, which produced a wide spectrum of pretty glows we observed around sunset and sunrise.

Astronomers can record glorious visions in daytime skies, too. Even peculiar cloud formations — gasp! — provide us with a colorful show. Orographic clouds form as moist air rises over dry mountains. Their opaque white color and extreme stability often combine to make them appear like giant birds hovering over the mountaintops. Iridescent clouds consist of numerous ice crystals of similar size. As sunlight refracts through them, it creates a rainbowlike pattern of colors.

But clouds scare most backyard astronomers. You may wish to stick with the nighttime light and color of the sky. Don't hesitate to try photographing these phenomena. You may discover that after taking your camera out and capturing some glorious visions, you've found a whole new area of astronomy to enjoy. □

William C. Livingston is a solar astronomer at the National Solar Observatory in Tucson, Arizona.

Sun block

On May 10 you'll see one of the last annular eclipses of the century. Make your plans *now* to secure a ringside seat for the big event.

by Jay Anderson

The date: April 7, 1940. The places: Texas, Louisiana, Mississippi, Alabama, Georgia, and Florida. The event: an annular eclipse of the Sun lasting seven and a half minutes. This spectacular event was a member of saros cycle 128, the 128th such cycle identified. Known since antiquity, the saros is a period of about eighteen years that elapses before a particular sequence of eclipses can recur in the same order. Following this period, the Moon, Sun, and Earth align in a similar way, creating the opportunity for an eclipse similar to the ancestors of the same saros cycle.

Just over 54 years later, on May 10, 1994, saros 128 returns to North America. It brings another annular eclipse, a ring of fire that will be visible from Baja California, Mexico, to the coast of Nova Scotia. The number of cities lying inside the path of annularity is astounding: Hermosillo, Mexico, El Paso, Oklahoma City, Wichita, St. Louis, Springfield, Illinois, Fort Wayne, Detroit, Toledo, Cleveland, Buffalo, Toronto, Rochester, Syracuse, Concord, New Hampshire, Montpelier, Vermont, Augusta, Bangor, and Halifax. These cities and others will see an annular eclipse lasting up to six minutes; other parts of North America will see a partial eclipse.

May's Broad Ring

Annular eclipses occur when the Moon slides across the face of the Sun at a distance from Earth too great to completely cover the solar disk. The result is a bright ring of sunlight surrounding the dark disk of the Moon. Depending on the relative sizes of the Sun and Moon, these rings of light can be narrow, as one was over the eastern seaboard on May 30, 1984, or they can be broad. The ring of sunlight for this May's eclipse will be relatively large: At maximum eclipse only 89 percent of the Sun will be covered.

The Moon's shadow first touches Earth's surface during this eclipse in the Pacific Ocean about 450 miles southeast of Hawaii. Residents of Hilo and Honolulu will see a half-eclipsed Sun rising up from the morning sea, climbing for half an hour before the last traces of the Moon depart from the Sun's edge. At the same time, viewers at Punta Eugenia on the Pacific coast of Mexico's Baja Peninsula will be watching the ring of sunlight as the Moon slips fully into the embrace of the Sun's limb.

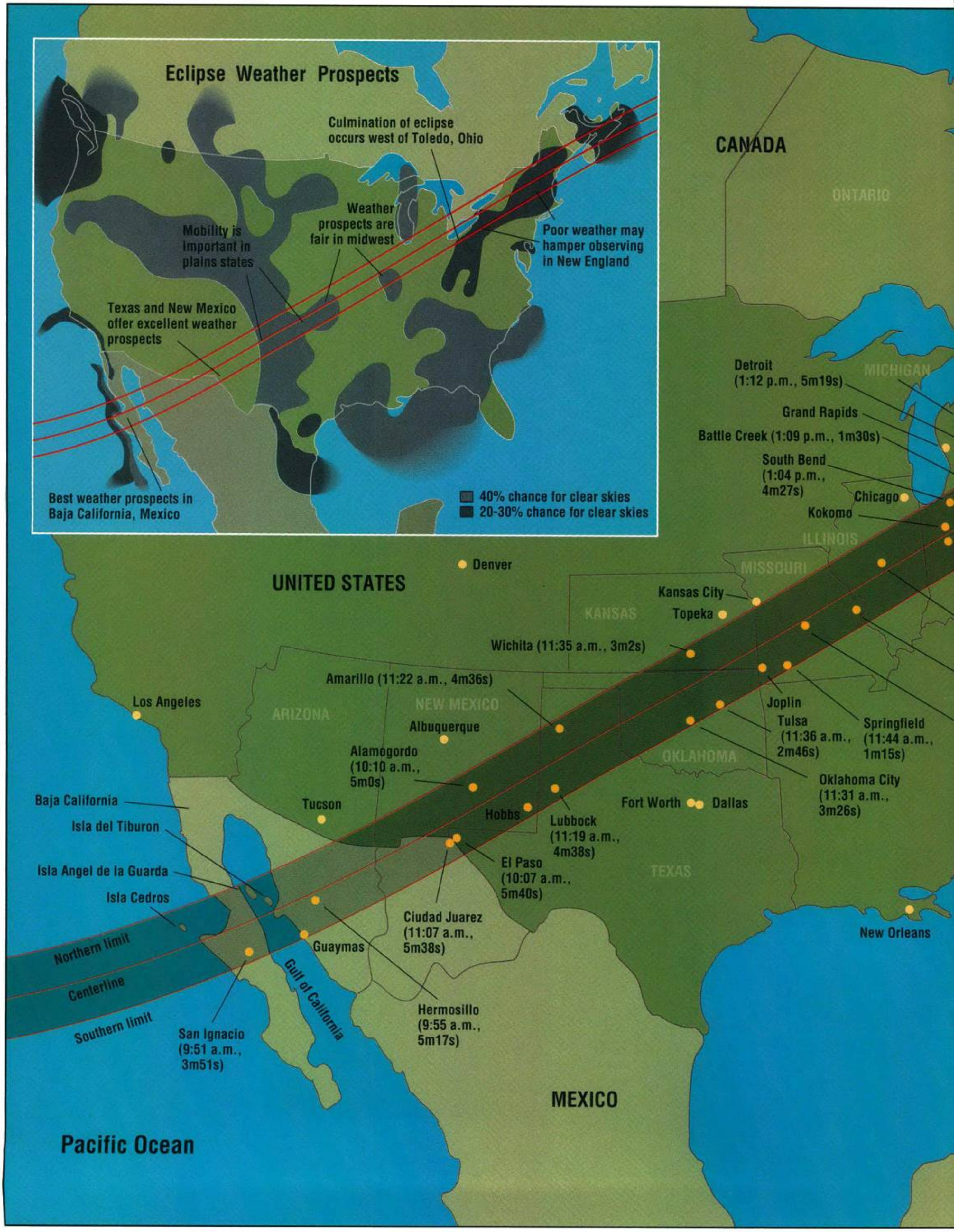
Over the next two hours the shadow will sweep across the rest of North America, racing at nearly three-quarters of a mile every two seconds, visible in a path varying from 145 to 170 miles wide. You need not travel to any exotic location to see this eclipse — it will come to you. After cutting a path across North America the shadow will touch Europe before the eclipse reaches a sunset ending over Morocco. Full observational details of the eclipse will appear in an upcoming issue. At this point, the most pressing question is where you should go to see the eclipse.

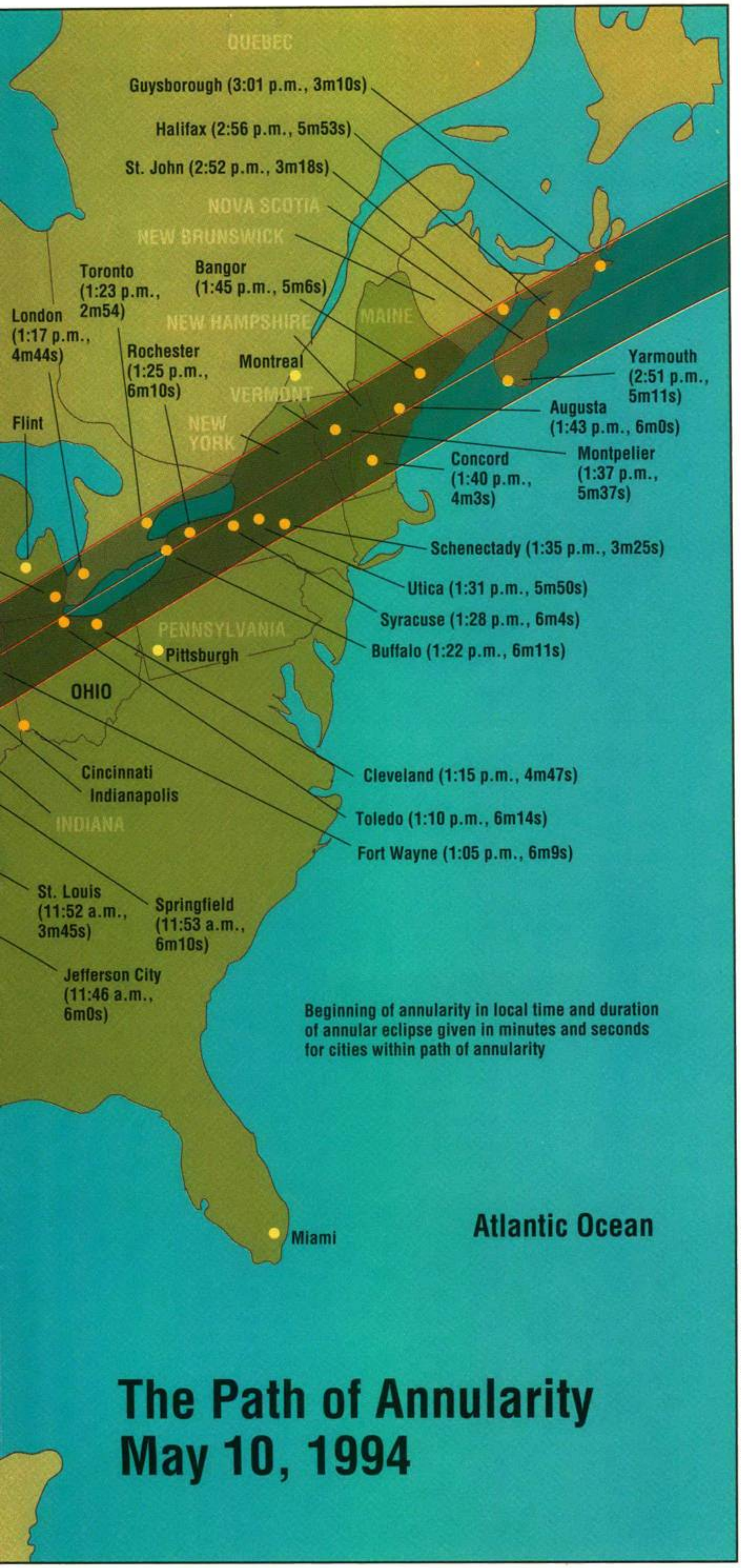
Eclipse Weather Prospects

As the Moon's shadow reaches the Baja California coast, the Sun will be nearly 40° above the horizon. Weather propects for this region do not promise success. Northwest winds frequently drag a marine layer of clouds over the shoreline. If you

A HOT RING OF SUNLIGHT surrounded the Moon during the annular eclipse of January 4, 1992. This May 10th, one will be visible across the United States.

Rondell J. Wilson


Eclipse Weather Prospects
Culmination of eclipse occurs west of Toledo, Ohio
Weather prospects are fair in midwest
Mobility is important in plains states
Poor weather may hamper observing in New England
Texas and New Mexico offer excellent weather prospects
Best weather prospects in Baja California, Mexico
▨ 40% chance for clear skies
■ 20-30% chance for clear skies
CANADA
ONTARIO
MICHIGAN
Detroit (1:12 p.m., 5m19s)
Grand Rapids
Battle Creek (1:09 p.m., 1m30s)
South Bend (1:04 p.m., 4m27s)
Chicago
Kokomo
ILLINOIS
MISSOURI
Denver
UNITED STATES
Kansas City
KANSAS
Topeka
Wichita (11:35 a.m., 3m2s)
Amarillo (11:22 a.m., 4m36s)
Los Angeles
ARIZONA
NEW MEXICO
Albuquerque
Joplin
Tulsa (11:36 a.m., 2m46s)
Springfield (11:44 a.m., 1m15s)
OKLAHOMA
Oklahoma City (11:31 a.m., 3m26s)
Alamogordo (10:10 a.m., 5m0s)
Baja California
Tucson
Fort Worth
Dallas
Hobbs
Lubbock (11:19 a.m., 4m38s)
Isla del Tiburon
Isla Angel de la Guarda
El Paso (10:07 a.m., 5m40s)
TEXAS
Isla Cedros
Ciudad Juarez (11:07 a.m., 5m38s)
New Orleans
Northern limit
Guaymas
Centerline
Gulf of California
Southern limit
Hermosillo (9:55 a.m., 5m17s)
San Ignacio (9:51 a.m., 3m51s)
MEXICO
Pacific Ocean


QUEBEC
Guysborough (3:01 p.m., 3m10s)
Halifax (2:56 p.m., 5m53s)
St. John (2:52 p.m., 3m18s)
NOVA SCOTIA
NEW BRUNSWICK
Toronto (1:23 p.m., 2m54)
Bangor (1:45 p.m., 5m6s)
London (1:17 p.m., 4m44s)
NEW HAMPSHIRE
MAINE
Rochester (1:25 p.m., 6m10s)
Montreal
Yarmouth (2:51 p.m., 5m11s)
VERMONT
Augusta (1:43 p.m., 6m0s)
Flint
NEW YORK
Montpelier (1:37 p.m., 5m37s)
Concord (1:40 p.m., 4m3s)
Schenectady (1:35 p.m., 3m25s)
Utica (1:31 p.m., 5m50s)
Syracuse (1:28 p.m., 6m4s)
PENNSYLVANIA
Pittsburgh
Buffalo (1:22 p.m., 6m11s)
OHIO
Cincinnati
Indianapolis
Cleveland (1:15 p.m., 4m47s)
INDIANA
Toledo (1:10 p.m., 6m14s)
Fort Wayne (1:05 p.m., 6m9s)
St. Louis (11:52 a.m., 3m45s)
Springfield (11:53 a.m., 6m10s)
Jefferson City (11:46 a.m., 6m0s)
Miami
Atlantic Ocean

Beginning of annularity in local time and duration of annular eclipse given in minutes and seconds for cities within path of annularity

The Path of Annularity May 10, 1994

Map by Thomas L. Hunt, after Jay Anderson and Fred Espenak

want to be among the first to see the annular eclipse from land, you'll have to take your chances with Baja's fussy weather. An inland bivouac, perhaps 15 miles from the ocean, will greatly increase the chances for clear skies. Baja's east coast promises better prospects but roads in the area are few and far between.

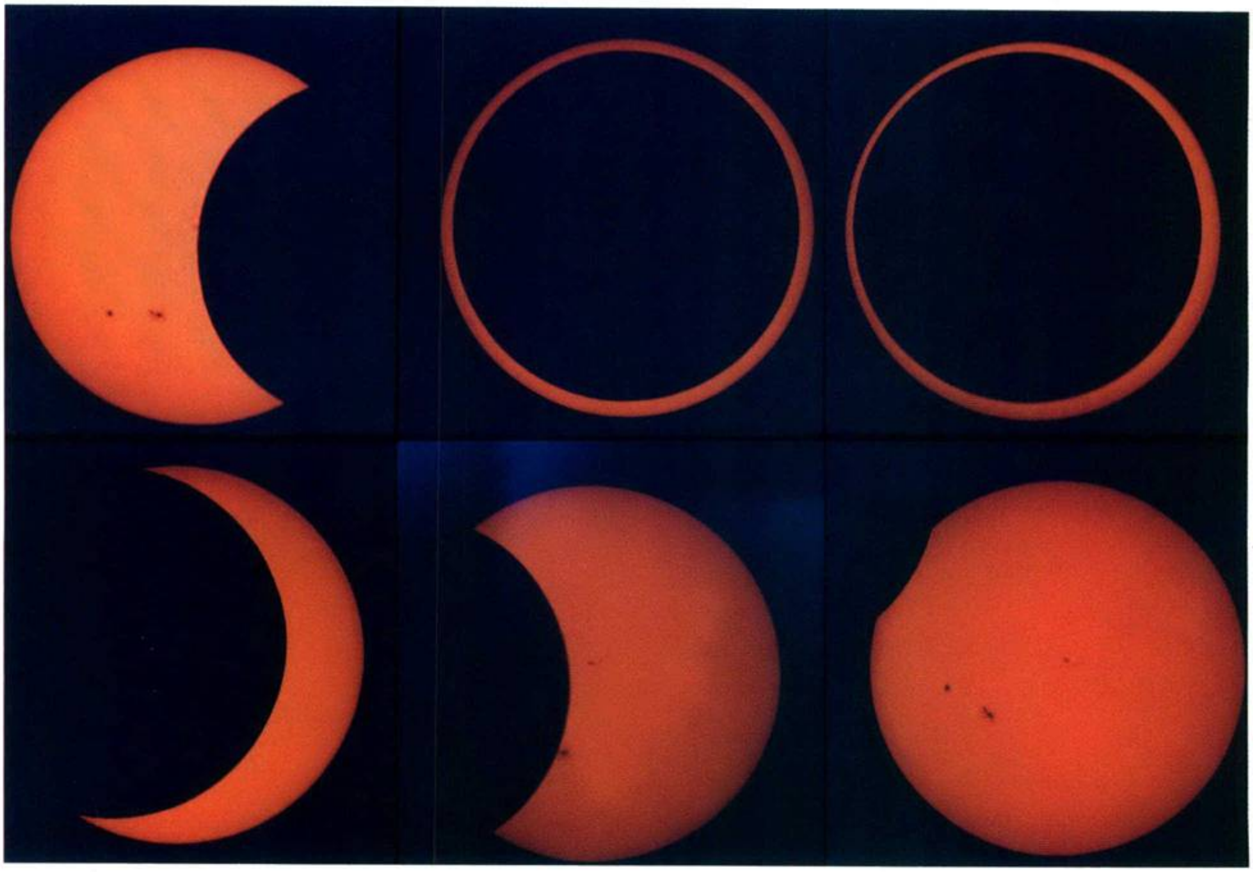
Once across the Baja coast the eclipse meets the finest weather prospects along its entire track. The Mexican coastline along the Gulf of California boasts sunny weather in May, typically with 24 clear days in a month. The 170-mile-wide track passes north of Guaymas, crossing almost directly over Bahia Kino. This small resort lies a short distance from Hermosillo and will be a choice destination for serious eclipse chasers. At this location the eclipse starts just before 10 a.m. local time, and annularity lasts 5 minutes and 30 seconds.

Into the States

Northern Mexico and the Southwestern United States offer similarly fine weather. Climatological records for this region show more than 300 hours of sunshine during an average May. For those who believe that the best location during an annular eclipse lies at the edge of the track, where Baily's Beads put on their grandest show, southeastern Arizona is the place to be. Records from the Bisbee-Douglas airport show 388 hours of sunshine during May. Statistics from past years show that nearly 75 percent of mornings have clear skies or scattered clouds.

New Mexico also offers great weather, but the prospects dim rapidly as the track cuts out over the Great Plains. During May a river of moist air flows north and east from the Gulf of Mexico, bringing a season of thunderstorms to the Midwest. Cloudiness increases rapidly across Texas as the track moves into the flow of moisture. As the track moves into Oklahoma and Kansas cloudiness increases slowly. The observers from the Texas Star Party who will travel north to Sierra Blanca southeast of El Paso should have a good chance for outstanding weather. Two days out of three should be clear near this site. Not so for those viewing from Oklahoma City or Kansas City, where the odds decrease to two days out of five.

If you view the eclipse from the Plains, get advance weather forecasts. Be ready with a vehicle to drive toward a better site during the last few hours preceding the eclipse. You can choose the best regional area a few



THE ANNULAR ECLIPSE of January 11, 1991, produced a fat ring (right center and bottom left). This May's eclipse will be similar.

days before the eclipse and then watch weather forecasts the night before. Be aware that thunderstorm activity can be difficult to predict.

If you stay in one place you'll have to take your chances with the weather — a risky prospect. The sky need not be perfectly clear. A little cloud can actually make an annular eclipse significantly more attractive. After all, annular eclipses lack some of the fancy trimmings of total solar eclipses — the corona, prominences, and shadow bands. So peek-a-boo clouds can add considerably to the spectacle.

Across the Father of Waters

East of the Mississippi, the eclipse approaches its longest duration and narrowest track. It seems that the opposite should be true — surely wide tracks and long durations go together — but during an annular eclipse the Moon is too distant to cover the Sun completely.

And so in Ohio, just west of Toledo, the eclipse culminates. Six minutes, thirteen and a half seconds click off between second and third contact. The width of the central path is down to 145 miles, the Sun a generous 66° above the horizon, but the weather prospects for sunny skies stand at a discouraging 40 percent.

Toward the East

As it moves across Lake Erie, parts of Ontario, and into New England, the shadow moves into a region of steadily worsening weather prospects. Towering spring thunderstorms join dull gray lows and frontal systems visiting from Canada. Both are influenced by the peaks of the Appalachian Mountains. These mountains force approaching weather systems to pause as they gather energy to cross the peaks and then climb to continue their eastward journey. Rising air cools, turning broken cloud to overcast, overcast to rain, rain to heavy rain. This culminates over New Hampshire where less than one third of the days in May enjoy good eclipse weather.

The effects of storm tracks and mountains may bring rather dismal expectations in the Northeast but at the same time Mother Nature dangles a jewel for those who wish to test the unfavorable weather. It's a game of odds. Typically the weather in this region is not good during May. But if a fresh cold front passes through the area just before eclipse day, brisk, sparkling clean air behind the front could bring clear, dark blue skies on eclipse morning. Despite its reputation, New England could have the last laugh in the end. If you stay in the region, keep an eye on the forecasts!

After Maine, the track skips across the Bay of Fundy and visits New Brunswick and Nova Scotia, the last stops on the North American part of the tour. Alas, there's no improvement in the weather, and the eclipse bids farewell to the continent in the same fashion it arrived — threatened again by fog and clouds brought by cool ocean currents. By now the eclipse is less than six minutes long, though it remains high in the sky at midafternoon. By 4:15 p.m. AST the last lunar nibble moves off the face of the Sun and saros 128 is finished in North America for another 54 years.

Whether you view this May's eclipse from the hot dry Southwest or cool moist Northeast, get ready now. If you live along the centerline and generally experience clear skies on early May mornings, you'll probably be able to sit tight and watch the eclipse from home. But if you want to travel to see the eclipse you should start planning where you'll go as early as possible. That will help ensure that the great annular eclipse of 1994 becomes one of your favorite memories of amateur astronomy. ☐

Jay Anderson is a meteorologist with Environment Canada who specializes in eclipse weather climatology.

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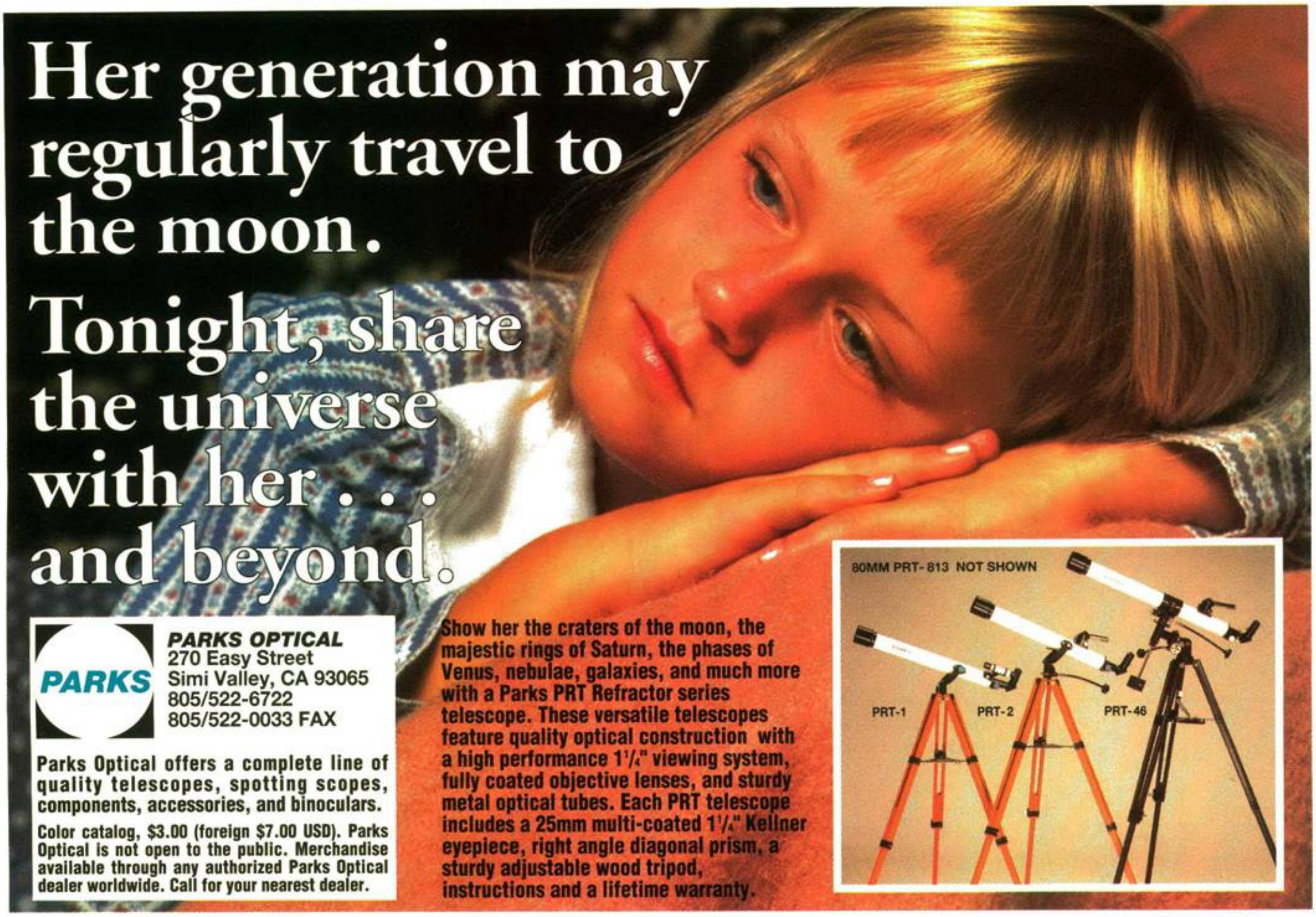
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Watch Mars Go Backwards

Like a circuit of race cars, the planets speed through their orbits around the Sun. When a planet more distant from the Sun than Earth nears opposition — a point opposite the Sun in the sky — Earth passes the planet due to its higher relative velocity, just as a faster car on an inner lane passes a slower car on an outer one. This causes the outer planet to appear to halt its normal apparent eastward motion in the sky and move westward, in so-called retrograde motion, before resuming its normal movement.

Capturing retrograde motion on film has long challenged backyard astrophotographers. The elaborate sky dance may last several months from start to finish. From his backyard in Havant, Hampshire, England, H. J. P. Arnold tackled the problem by taking a series of individual photographs and combining them in his darkroom. The result is a single image showing the retrograde loop through Gemini displayed by Mars as Earth passed it from November 1992 to February 1993.

Arnold used a 50mm lens at f/2.8, Ektachrome 400 film, and exposures of 5 to 10 minutes for the images. His collection of Mars loop images consisted of 57 exposures as he went into the darkroom phase of the project. With the help of a professional color laboratory, Arnold copied the images onto a single master and produced films. He had captured a Martian loop.

The King and I. Dozens of reports on Jupiter's belts and bands, many containing drawings, rolled into our offices in 1993. On April 9, José Olivarez, an experienced planetary observer from Wichita, Kansas, predicted a transformation of the South Equatorial Belt. "A dark feature in the SEB may suggest a major transformation lies ahead," said Olivarez. Indeed it did. Olivarez's subsequent sketches, made with an 8-inch refractor, show a bluish disturbance expanding through the SEB.

During May Dan Troiani of Schaumburg, Illinois — a Mars Recorder for the Association of Lunar and Planetary Observers — chronicled the disturbance in a series of sketches. Finely detailed drawings by Mike Zweifel of Sturtevant, Wisconsin, compared favorably with those made by Troiani.

During the same month in West Haven, Connecticut, Michael Amato, Joseph Cseh, and Anthony Amato found the SEB "fully developed" and the Great Red Spot "salmon pink" in color. The trio used a 10-inch SCT at 201x and 333x.

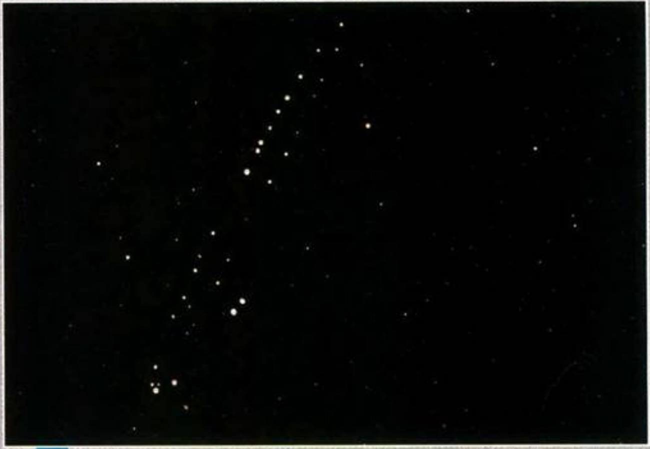
Mike Green of Waco, Texas, boosted the magnification of his 8-inch f/10 SCT to 500x on May 6, 1993, and was astounded to see the planet's four bright moons as disks. Have other readers used small telescopes to see the Galilean satellites as disks?

Eyes on a Frozen World. Readers continue to send us reports of their successful sightings of Pluto last summer, following the article "Pluto Watch" (May 1993). On June 16, 1993, Chris Thomas and Dan Hatton set out to spot Pluto from Dan's yard on a dark hilltop near Ripley, New York. "Earlier in the year we had tried to see the distant planet several times," says Thomas, "but were always hindered by haze and unpredictable clouds. The sky on June 16 was good but not ideally transparent."

The New Yorkers were surprised. "We succeeded first with Dan's 13-inch scope and then saw it in an 8-inch SCT, both at relatively high power. In each case, Pluto was the faintest object visible in the field. "Pluto season is the highlight of my year in astronomy," says Thomas.

From Traverse City, Michigan, Bob Shindorf reported spotting Pluto on several nights in mid-July 1993. Shindorf used a 13.1-inch f/4.5 reflector at 115x and 202x. On July 12 he noted that Pluto was visible almost continuously with averted vision at both magnifications. ☐

ASTRONOMY wants to hear about your observations of the sky. Please send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187.



Mars Displays Its Retrograde Loop

by H. J. P. Arnold (50mm f/2.8 lens, Ektachrome 400 film, composite image taken between October 5, 1992, and May 5, 1993)

Jupiter and Its Red Spot

by Donald G. Bruns (8-inch SCT at f/140, Ektar 100 film, 6-second exposure on March 25, 1993, using Wratten 82C and 2B filters and an AO-2 image stabilizer)

Perseids Streak Overhead

by Michael Kobusch (30mm f/3.5 fisheye lens and homemade all-sky camera, Ektachrome 200 film, 55-minute exposure taken on August 11/12, 1993)

The Veil Nebula (NGC 6992-5)

by Bill and Sally Fletcher (16-inch f/4.5 reflector, tricolor image made from 65-minute (red), 90-minute (blue), and 125-minute (green) exposures on hypersensitized Tech Pan film)

Spiral Galaxy NGC 7184

by Martin C. Germano (14.5-inch f/5 reflector, hypersensitized Tech Pan film, 70-minute exposure)

INTO THE CENTER OF THE GALAXY

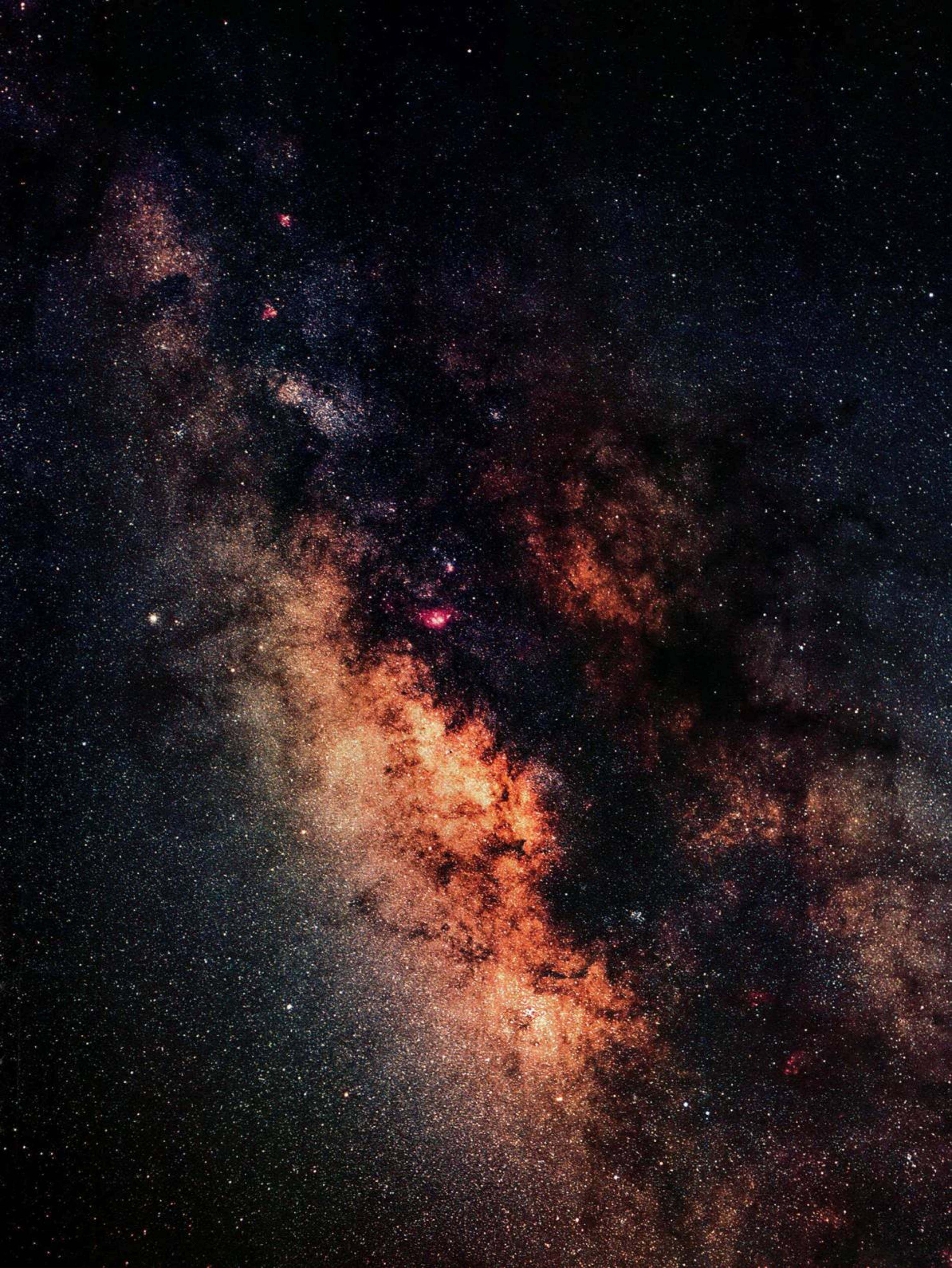
Anyone who has stared into the constellation Sagittarius has seen the crowd of stars concentrated toward the center of the Milky Way. Its magnificent beauty paints the surrounding sky, which is studded with clusters and nebulae. Peter Ledlie's photo of the Sagittarius area (opposite page) wins this month's $100 "Best Astrophoto" award.

Ursa Major Trails over Bryce Canyon

by Joshua Vaughan

The Sagittarius Star Cloud

by Peter Ledlie (105mm lens at f/3, Pentax 6x7 camera, composite of two 30-minute exposures on hypersensitized Fujicolor 100 film)



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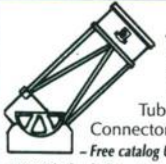

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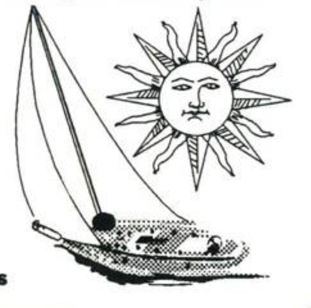

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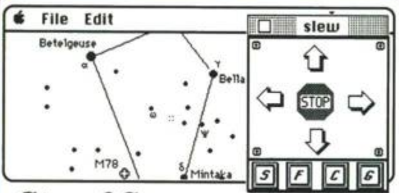

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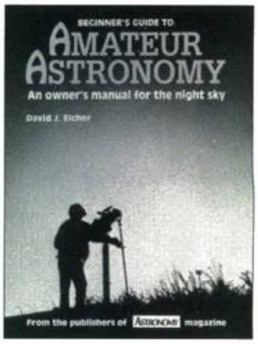
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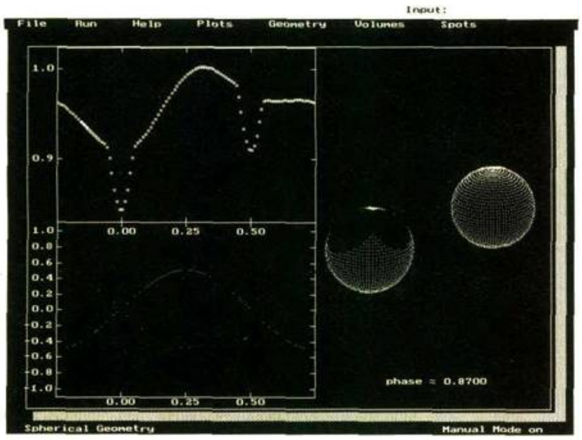

Did you ever wonder how astronomers determine the sizes and shapes of stars in an eclipsing binary star system from just the brightness of the stars? Binary Maker takes away the mystery and lets you explore both binaries you have observed and 43 systems that have information in the program's database. Advanced observers, armchair astronomers, and professionals will all find this program a useful tool for studying binaries.

To study the light curves of binaries, especially eclipsing binaries, you need to investigate how one star covers the other's surface and blocks its light. Binary Maker lets you create 3D representations of the surface of both stars. It allows you to set their radii and temperatures, add spots, include heating of one star's surface by the other, gravitationally distort the surfaces of close binary stars, and specify the observer's viewing angle.

After building a binary system, you can let one star orbit the other and calculate the system's brightness. For the systems in the database, this brightness plot appears on your display superposed on an observed brightness curve for the system. The display also shows how the velocity of each star changes through its orbit, again being superposed on the observed velocities. You can change your model for the binary system to improve the fit between the calculated and observed curves. A spectrum synthesizer shows you how the shapes of spectral lines appear at different points in the orbits. You can print all these results on a PostScript printer.

A second program provided with Binary Maker allows you to analyze velocity curves to determine the masses of the stars in a binary. You can do this interactively or let the computer find the numbers for you.

The manual provides five tutorials to teach you how to use Binary Maker as well as two exercises to teach you about binary star systems. These exercises can also be used in college classrooms or by advanced high school students. Although Binary Maker is a professional-level program, the tutorials explain all the terminology and the manual provides the information you need to start modeling binaries.

I highly recommend Binary Maker to anyone wanting to explore binary stars and also to those folks who want to expand their horizons past star charting programs. The program is reasonably priced considering its power and its professional results. I tested it on a 25 MHz 80386-based machine and it ran fine for simple stellar models, but you'll want to use a faster computer for detailed calculations. — *Dave Bruning*

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Catalogue (HR), Smithsonian Astrophysical Observatory (SAO) Star Catalog, Hubble Guide Star Catalog (GSC), and General Catalog of Variable Stars. All the New General Catalogue (NGC) objects and over 30,000 galaxies from other catalogs make up the deep-sky database.

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Redshift (version 1.0)
Maris Multimedia Ltd., 99 Mansell Street, London E1 8AX, England. In the U. S., call (800) 336-0185; from overseas and Europe, call (44) 71 488 1566. Price: $99. Minimum requirements: Macintosh LC II, System 7.0, 4 MB of memory, CD-ROM drive, 1.5 MB of free hard disk space, and a color monitor. Recommended: 5 MB of memory; large monitors may require more memory.

Redshift is probably the first multimedia program to emerge from Russia. It offers the features of a planetarium-type program, letting you display the positions of stars, planets, and deep-sky objects. The databases contain about 250,000 stars, 40,000 deep-sky objects, and over 5,000 asteroids. Most positions are accurate to about 10 to 30 arcseconds from 4712 B.C. to A.D. 10,000. Use of the Jet Propulsion Lab's DE 102 ephemeris improves positional accuracy to a couple of arcseconds from 1850 to 2050.

The program allows you to choose which stars, planets, asteroids, and deep-sky objects are displayed. The FIND feature uses a menu to show information or center on an object. If you want to see which planets are up this month, you can use the planet visibility feature that shows when the planets rise and set in tabular or graphical form. The program also includes Jacqueline Mitton's *Dictionary of Astronomy* with illustrations and animations.

Perhaps the most novel feature of Redshift is its graphics. You can explore a photo and movie gallery (running under QuickTime, which is provided with Redshift), make movies of views you create with Redshift, move around and track 3D models of the planets and their moons, and view surface maps of Earth, the Moon, and Mars. You can print these graphics as well as star charts. ☐

MEETINGS & EVENTS

February 7-13
Winter Star Party, Key West, Florida. Sponsored by the Southern Cross Astronomical Society, Inc. Contact Bob or Sharon Grant, 5401 SW 110 Avenue, Miami, FL 33165, (305) 595-8778.

February 18-23
AAAS Annual Meeting, Hilton and Towers, San Francisco, California. Sponsored by the American Association for the Advancement of Science. Contact AAAS Meetings Office, 1333 H Street N.W., Washington, DC 20005, (202) 326-6450

March 5
Astroimage 94, California State University, Fullerton, California. Sponsored by the Orange County Astronomers, the Ventura County Astronomical Society, and the Physics Department of California State University. For program information, contact John Sanford, 2195 Raleigh Avenue, Costa Mesa, CA 92627, (714) 722-7900. Submit papers to Wayne Johnson at the same address, (714) 646-7578.

March 14-18
25th Lunar and Planetary Science Conference, NASA Johnson Space Center, Houston, Texas. Sponsored by the Lunar and Planetary Institute and the NASA Johnson Space Center. Contact LeBecca Simmons, LPI Publications and Program Services Department, 3600 Bay Area Boulevard, Houston, TX 77058, (713) 486-2158.

March 18-20
The Gathering at the Equinox, Museum of York County, Rock Hill, South Carolina. Sponsored by the Carolina Skygazers. Contact Barbara or Glenn (803) 329-2121.

April 7-10
First Annual Peach State Star Gaze, Future Farmers of America campground outside Covington, Georgia. Sponsored by the Atlanta Astronomy Club. Contact Ken Poshedly, 3440 Everson Bay Court, Snellville, GA 30278, (404) 979-9842. ☐

Clubs, please submit announcements at least four months before the date of the event. Readers, when writing to organizations listed in "Meetings and Events," include a self-addressed, legal-sized envelope with your request for information.

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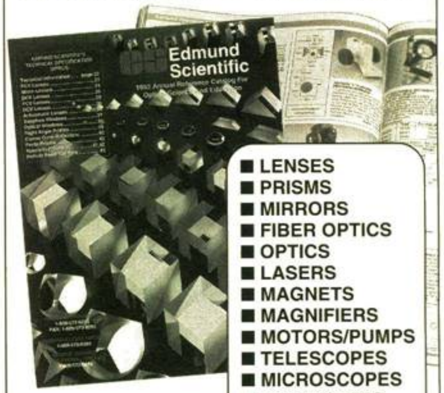

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See the Meade ad in this magazine for full specifications and product descriptions. ED = Extremely low dispersion glass which yields color-free virtually perfect images. PPEC = Permanent Periodic Error Correction "Smart Drive."

Model 102 ED 4" f/9 Apochromat & mount (add $105 P&S)	**$2195**
Model 127 ED 5" f/9 Apochromat & mount (add $125 P&S)	**$2795**
Model 152 ED 6" f/9 Apochromat & mount (add $185 P&S)	**$4495**
Model 178 ED 7" f/9 Apochromat & mount (add $215 P&S)	**$5495**
Medium format adapters ..... Mamiya 645, **$98;** Pentax 6X7,	**$98**
Med. format EASY-GUIDER™: Mamiya 645, **$298;** Pentax 6X7,	**$298**

DRIVE SYSTEMS

#1664 Electronic Drive with PPEC & 2X, 32X slewing system	**$375**
#1697 Computer Drive, 747 object computer memory, automatic slewing to desired object	**$695**
8,000 Object CNGC Library .. **$99** Polar alignment finder ..	**$99**

OPTICAL TUBE ASSEMBLIES (OTA)

Model 102 ED/OTA 4" f/9 OTA only (add $55 P&S)	**$1045**
Model 127 ED/APO-OTA 5" f/9 OTA only (add $60 P&S)	**$1595**
Model 152 ED/APO-OTA 6" f/9 OTA only (add $100 P&S)	**$2295**
Model 178 ED/APO-OTA 7" f/9 OTA only (add $120 P&S)	**$3250**
Cradle ring assem. 4" (4½" OD tube) **$135;** 5" (5½" OD tube)	**$145**
Cradle ring assem. 6" (7" OD tube) **$169;** 7" (8" OD tube)	**$219**

EQUATORIAL MOUNTS

LXD 600 mount and standard field tripod (add $60 P&S)	**$1350**
LXD 700 mount and giant field tripod (add $100 P&S)	**$2250**

NOTE: Add the indicated packing and shipping (P&S) costs to each telescope for insured UPS shipment to your door.

MEADE SERIES 4000 PREMIUM EYEPIECES

6.4, 9.4, 12.4, 15, 20, 26mm Plossl	**$88**
32mm, 40mm Super Plossl	**$110**
56mm Super Plossl (2") ***THE BEST****	**$230**
13.8mm Super Wide Angle	**$140**
18mm Super Wide Angle	**$150**
24.5mm Super Wide Angle	**$170**
32mm Super Wide Angle (2")	**$240**
40mm Super Wide Angle (2")	**$299**
4.7mm Ultra Wide Angle	**$155**
6.7mm Ultra Wide Angle	**$188**
8.8mm Ultra Wide Angle (1¼/2")	**$230**
14mm Ultra Wide Angle (1¼/2")	**$270**

Shipping charges of 1-2% are extra.

**Plossl test, "SKY & TELESCOPE," p490-492, May 1988*

NEW MEADE 12" LX200 SCHMIDT-CASSEGRAINS

8" LX200
$2295
12" LX200 $3995

NEW Meade 8" LX200 Telescopes

See the Meade ad in this magazine for full specifications & details. **LX100 Drive**, 2X, 32X speed control with PPEC (Permanent Periodic Error Correction "Smart Drive") & dual-axis hand controller. **LX200 Drive**, Full electronic control with PPEC, 747 object computer memory and automatic computer controlled slewing to desired object. *NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your Schmidt-Cassegrain.

8" LX100 Schmidt-Cassegrain with wedge (add $105 P&S)	**$1995**
8" LX200 Schmidt-Cassegrain with computer (add $105 P&S)	**$2295**
Wedge for photographing with 8" LX200	**$110**
10" LX100 Schmidt-Cassegrain w/super wedge (add $145 P&S)	**$2695**
10" LX200 Schmidt-Cassegrain with computer (add $145 P&S)	**$2595**
NEW! 12" LX200 (f/10 only) with computer (add $215 P&S)	**$3995**
Super Wedge for photography with 10" or 12" LX200	**$395**
8,000 Object CNGC Library (Version 2.5 software)	**$99**
Library Option 1: 10,600 obj. selected from NGC, Messier, IC catalogues	**$99**
Library Option 2: 64,350 celestial objects (Version 3.2 only)	**$149**

OTHER SCHMIDT-CASSEGRAINS

Meade 2045D 4" f/10 with motor drive (add $40 P&S)	**$699**
Meade 2080B 8" f/10 with tripod, wedge, MCOG (add $85 P&S)	**$1149**
NEW! Model 2120B 10" f/10 w/wedge, tripod, MCOG (add $125)	**$1449**

PHOTOGRAPHY ACCESSORIES

LUMICON Cassegrain EASY-GUIDER f/6 or f/10	**$225**
LUMICON Giant EASY-GUIDER for 10" f/5-f/10 operation	**$395**

MEADE STARFINDERS

New 8" f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions and technical specifications for 6" to 16" Starfinders. These are complete telescope systems with motor drive, mount, finderscope and 25mm (=48X) eyepiece.

6" f/8 Starfinder 6(add $50 P&S)	**$599**
8" f/6 Starfinder 8 (add $60 P&S)	**$699**
10" f/4.5 Starfinder 10 (add $75 P&S)	**$799**
16" f/4.5 Starfinder 16 (ship. freight COD)	**$2195**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated shipping charge to the price. LUMICON showroom prices are $96 higher.

ACCESSORIES

LUMICON carries the full line of Meade accessories. See the Meade ad in this magazine for detailed prices and descriptions.

LUMICON Single axis drive corrector	**$99**
LUMICON DX200 Dual-axis drive cor.	**$249**
Meade 47M Dual-axis drive corrector	**$450**
LUMICON DX2BP Dual-axis drive corrector with built-in battery pack	**$299**

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- "GUIDE" mode leads you to object
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- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $399

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $499

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

NGC SKY VECTOR™ $699

IMPROVED!—5500 Additions / Corrections

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Improved NGC SKY VECTOR with over 12,000 object memory including the planets, complete, corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2" EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8".

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6X7	**$129.00**
2" Adapter for Hasselblad	**$229.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

2" DELUXE BARLOW

1.8x Multiplier Lens (2" Barlow)

LUMICON 1.8x Multiplier Lens (2" Barlow)	**$235.00**

LARGE UV/DUST SEAL

Protect the optics of your 8-14" Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080	**$119.50**
UV/Dust Deal for Celestron C-8	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14	**$89.50**

LOW PROFILE FOCUSERS New! Thread-on for Odyssey

FROM $59.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Coulter Odyssey (thread-on installation), Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$59.50**
LUMICON 2" Helical Focuser 1½" high	**$65.00**
LUMICON Non-rotating Helical Focuser	***$129.00***
2" Astro Systems focuser, only 2" high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" **adapter** w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$59.50**, right-angle	**$59.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle 80mm SUPER-FINDER	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
Large mounting rings for 80mm Finder	**$55**
1¼" Star Diagonal **$39**, Mounting Brackets,	**$39.50**
1¼" 45° diagonal for correct left-right views	**$52.44**

LOTS OF ADAPTERS

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2" adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1" long 1¼" OD thread-in extension	**12.00**
2½" long extension (holds 1¼" filters)	**16.00**
4½" long extension for 1¼" eyepieces	**$25.00**
3" long extension for 2" eyepieces*	**$26.00**
2" long extension for 2" eyepieces*	**$26.00**

VIEWING ADAPTERS

2"/1¼" reducing bushing, threaded 48mm*	**$20.00**
2"/T-thread adapter, threaded 48mm*	**$25.00**
T-thread/1¼" adapter	**$25.00**
F/10 2" or 1¼" eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2" Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

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ASTROPHOTO OF THE MONTH

NGC 2024, the "Flame" or "Christmas Tree" nebula in Orion. 40 minute photo by Donn Reiners using hypered 2415 film and a LUMICON 2" Easy-Guider with 16" f/5 telescope. This combination reflection / emission nebula is seen best with either a LUMICON Deep-Sky or a LUMICON UHC filter.

"I'd Pick The TELE VUE™"

40mm Wide-Field Test, "Astronomy," Aug. 1990, p. 90

NEW! Genesis-SDF 4" f/5.4 SD-fluorite	**$1885**
Pronto 70mm f/6.8 apochromat w/2" diagonal	**$825**
Pronto 70mm f/6.8 w/45° erecting prism	**$725**
Complete Equatorial Mount	**$795**
Motor Drive for above mount	**$239**
7.4, 10.4, 13, 17, 21, 26mm Plossl 50°	**$79**
1.8x or 2.5x Tele Vue Barlow Lens	**$89**
2" Giant Barlow - 2x	**$189**
32mm Plossl, widest true field in 1¼"	**$109**
55mm 2" Plossl, widest possible field	**$219**
15mm Wide-Field, 1¼" eyepiece, 65°	**$135**
19mm Wide-Field, 1¼" eyepiece, 65°	**$145**
24mm Wide-Field, "Rich-Field!" 65°	**$169**
32mm Wide-Field, 2" eyepiece, 65°	**$239**
40mm Wide-Field, "Rich-Field!" 65°	**$299**
4.8mm Nagler, 82° field, 1¼" eyepiece	**$149**
7mm Nagler, 1¼" eyepiece, 82° field	**$189**
9mm Nagler, 82° field, 1¼" or 2"	**$219**
13mm Nagler, 82° field, 1¼" or 2"	**$249**
12mm Nagler, Type II, 82°, 1¼"/2"	**$249**
16mm Nagler, Type II, 82°, 1¼"/2"	**$289**
20mm Nagler, Type II, 82°, 2" only	**$340**
1¼" Paracorr Visual Coma Corrector	**$159**
2" Paracorr Visual Coma Corrector	**$249**
NEW! 15mm Panoptic 1¼", 68° field	**$199**
NEW! 22mm Panoptic 1¼"/2", 68°	**$249**
NEW! 27mm Panoptic 2", 68° field	**$299**
NEW! 35mm Panoptic 2", 68° field	**$325**

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.

LUMICON Adjust. Piggyback Mount **$59.50**
Specify telescope size: 6", 8", 10", 11", 14", 16"

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Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

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46, 48, 49mm	**$59.00**	**$49.00**
52, 55, 58, 62mm	**$69.00**	**$59.00**
67, 72, 77mm	**$79.00**	**$69.00**
82mm	**$89.00**	**N/A**

Hypered 2415 film, 36 exp .. **$10.95, $3/$29**

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LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$39.50**	1.52"	**$45.00**	1.83"	**$49.50**
2.14"	**$59.50**	2.60"	**$75.00**	3.10"	**$99.50**

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$159.00**

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."
ASTRONOMY February 1991

AMAZING OIII FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90-96% for both O-III lines at 496nm and 501nm.

SEE THE HORSEHEAD!

Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.

"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*

Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."*

Astronomy, Feb. 1991

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	**$59.50**
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48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	**$299.50**
2" Rear Cell Filter, fits SCT's ... Deep-Sky, **$119.50** UHC, O-III, H-Beta,	**$199.50**
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48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$199.50**
Set of both premium **DEEP-SKY** and **UHC Filters** (Save 11%) ... 1¼" **$159.50**; 48mm	**$279.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** ... **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines ... **1¼" $99.50, 48mm**	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	**$20.00**

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DEEP-SKY ASTROPHOTOGRAPHY

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U.S. Patent 4,473,636

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Specify Camera and Telescope type.

U.S. Patent 4,448,500

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Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
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Pentax 6X7 **add $119;** Pentax 645 **add $139**

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Pentax 6X7 **add $119;** Pentax 645 **add $139**

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For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

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Adapter for Hasselblad **$229,** Mamiya 645**$129**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

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Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 30Hz/90Hz variable output controls telescope drive. 60Hz digital reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Dec. reverse switch for Newtonians.

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Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SR-G3200, fastest of all, color neg	24	**$13.95**
Kodak Ektar 1000 fast, fine grain	24	**$12.95**
Fuji HG400 fine grain color neg.	12	**$10.95**
3M 1000, fastest slide film	12	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

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Mark Davenport, Pinellas Park, Fla.

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David Broad, Santa Barbara, Ca.

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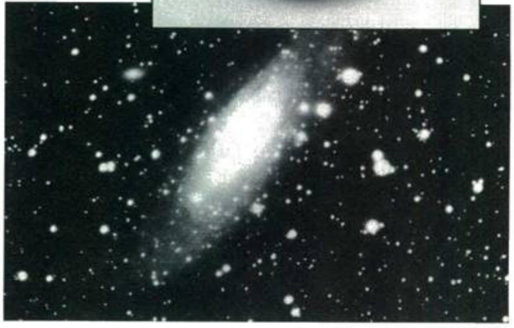


Starlight Xpress CCD Camera

This new 500 x 256-pixel cooled CCD camera uses an external electronic module to store image frames. The image is continuously displayed on a monochrome TV monitor in full resolution only 1.5 seconds after you give the readout command. A computer is not needed to acquire images but is required for saving and enhancing images. The Sony CCD chip has an active area 6.4 by 4.35 mm. It uses 12.7 x 16.6-micron-sized photodiodes in an interline array — image data from each row of photodiodes is shifted to an adjacent row of masked photodiodes, yielding fast image readout. Tiny lenses over each of the exposed diodes concentrate the incoming light onto these diodes, minimizing loss of image from the rows of masked diodes. The sample image shown is a 163-second exposure of M31 taken through a 135mm telephoto lens.

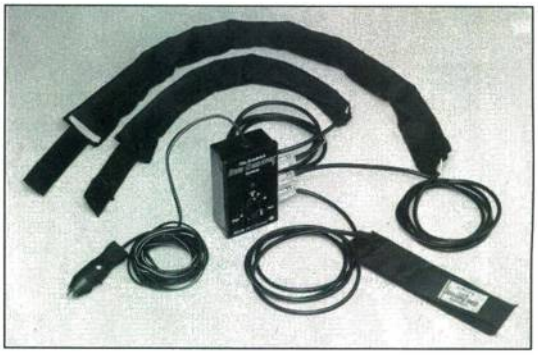
John Sanford, 2195 Raleigh Avenue, Costa Mesa, CA 92627, (714) 722-7900, fax (714) 646-7578. Introductory price: $1,995.

PXL Modular CCD Camera

The PXL CCD camera system by Photometrics delivers readout rates up to 4 million pixels per second and features low noise and high linearity. The system supports passive air, forced air, and liquid cooling in a single camera head. The PXL system is available with a choice of CCD arrays, including the new Kodak KAF6300 (3,072 x 2,048 pixels).

Photometrics, Ltd., 3440 E. Britannia Drive, Tucson, AZ 85706, (602) 889-9933. Call or write for information and prices.

Kendrick Dew Remover System



This unique anti-dew system consists of a controller box that plugs into any 12-volt DC or AC source. (Kendrick recommends a deep-cycle marine battery.) The controller can accommodate up to five anti-dew heater coils, varying the output power from 40 to 100 percent (lower settings save battery power). Kendrick offers heater coils in nine sizes for telescopes up to 14-inch Schmidt-Cassegrains. Heater coils for eyepieces and Telrad finders are also available. The controller box has a Velcro backing to allow users to fasten it to any mount or tube. Each coil also has Velcro end tabs to hold it in place when wrapped around a tube.

Jim Kendrick, 2775 Dundas Street W., Toronto, Ontario, Canada M6P 1Y4, (416) 762-7946, fax (416) 767-4112. Controller: $47; Telrad: $30; 0.965/1.25-inch: $29; 1.25/2-inch: $29; 3-inch: $32; 4- to 5-inch: $34; 5.5- to 6.5-inch: $37; 7- to 8-inch: $40; 10- to 11-inch: $44; 14-inch: TBA.

Premium Binoculars from Steiner

Commander
7x50
STEINER

The Steiner 7x50 Commander III binoculars (shown) feature Steiner's CAT (color adjusted transmission) coatings and an integrated through-the-lens compass lit by an LED. Designed for marine use, the binoculars are waterproof and shock resistant. The 8x30 Firebird II (not shown) is equipped with a fire-red objective lens coating that blocks 100 percent of UV-B and UV-A light. The Firebird has an eye relief of 20mm and features a shock-resistant polycarbonate body.

Pioneer Research, 216 Haddon Avenue, Suite 522, Westmont, NJ 08108, (609) 854-2424. 7x50: $1,399; 8x30: $399.

Timberline Image Processing Workstations

Timberline's high-performance image-processing computers each feature three 32-bit microprocessors: an Intel 486DX2 66, a Weitek P9000 graphic accelerator, and an Intel 80376 caching controller. All models can be configured with up to 256 megabytes of RAM and multiple 3.4-gigabyte drives.

Timberline, 766 Fulmer Court, Meridian, ID 83642, (208) 887-0969 (phone or fax). Prices start at $3,995.

Portable Photo CD Player

The PCD 970 is a full-featured audio CD player that also reads Kodak Photo CD disks, displaying digitized images on any television. The PCD 970 also features continuous-sound capability for future Photo CD disks that will display a series of images over a continuous soundtrack. The unit operates on four AA batteries.

Eastman Kodak Company, 343 State Street, Rochester, NY 14650-0519, (800) 242-2424, ext. 77. $449.

Kodak
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LED Spector Lights

These new observers' flashlights use LEDs for long battery life (they use two AA cells). You can order them with either red or green LEDs and with either narrow or wide beams. Each Spector Light features a splash-proof anodized aluminum case available in a variety of colors.

LEDTRONICS, Inc., 4009 Pacific Coast Highway, Torrance, CA 90505, (310) 534-1505, fax (310) 534-1424. $45.

This department presents new product announcements issued by their manufacturers. Product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send us their product announcements.

Precision Solar Filters

Thousand Oaks Optical solar filters are recognized around the world for their quality, consistent density and even coating across the entire aperture. We specialize in solar filters only and are the largest solar filter manufacturer in the world. Filters are available to fit all brands of telescopes and binoculars. **Thousands of our filters are in use around the world. The preferred choice of telescope dealers and exclusively used by NASA aboard the Space Shuttle.**

GLASS - TYPE 1 *(Full Aperture)*

Made from high quality hand select glass, machine polished and TRIPLE COATED with a Nickel-Chromium alloy (same as Inconel). Mounted in a machined aluminum cell ready to attach to telescope. Solar image is yellow-orange. No secondary filtering is necessary.

Aperture	Mounted	Aperture	Unmounted
2.4"	$49.00	2.4"	$39.00
3.1"	52.00	3.1"	42.00
3.5" to 4"	59.00	3.5 to 4"	49.00
4-1/4" to 5"	74.00	4-1/4" to 5"	64.00
6"	79.00	6"	69.00
8"	95.00	8"	85.00
10"	109.00	10"	99.00
11"	119.00	11"	109.00
12.5" to 13.1"	149.00	12.5" to 13.1"	129.00
14"	169.00	14"	149.00

40mm to 80mm Binoculars - Mounted .... $92.00 pr.

GLASS - TYPE 2 *(Full Aperture)*

Same as type 1, except stainless steel is combined in the coating to provide an even more durable surface that highly resists wear due to excessive handling and ultraviolet radiation. Solar image is also yellow-orange.

Aperture	Mounted	Aperture	Unmounted
2.4"	$62.00	2.4"	$52.00
3.1"	65.00	3.1"	55.00
3.5" to 4"	76.00	3.5 to 4"	66.00
4-1/4" to 5"	96.00	4-1/4" to 5"	86.00
6"	105.00	6"	95.00
8"	125.00	8"	109.00
10"	139.00	10"	119.00
11"	149.00	11"	139.00
12.5" to 13.1"	179.00	12.5" to 13.1"	159.00
14"	199.00	14"	179.00

40mm to 80mm Binoculars - Mounted .... $115.00 pr.

GLASS - TYPE 3 *(Full Aperture)*

Coated to a neutral density of 4 for serious astrophotographers who desire the shortest possible shutter speeds with slow films. Solar image and optical quality same as type 1 & type 2. Type 3 filters are for photographic use only.

Aperture	Mounted	Aperture	Unmounted
2.4"	$79.00	2.4"	$65.00
3.1"	82.00	3.1"	69.00
3.5" to 4"	99.00	3.5 to 4"	79.00
4-1/4" to 5"	125.00	4-1/4" to 5"	110.00
6"	135.00	6"	115.00
8"	159.00	8"	139.00
10"	172.00	10"	152.00
11"	199.00	11"	179.00
12.5" to 13.1"	229.00	12.5" to 13.1"	209.00
14"	259.00	14"	239.00

Threaded camera filters also available.

Types 1 & 2 are for unlimited visual use and general photographic use. Instructions included with all filters, including tips on solar photography.

Our glass filters are more durable than ANY Mylar filters on the market. If you're looking for the most economical filter, we now offer the same type of Mylar filters sold elsewhere, and our prices are reasonably lower. Unlike the competition, we charge the same price for each aperture regardless of brand. We don't charge more if you have an expensive refractor or Maksutov. Sample pricing: C-90 or 2045 - $42.00, C-8 or 2080 - $79.00. Unmounted Mylar is also available.

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Priced from $699-$859 complete
& ready to attach to telescope.

If you see a lower price on any copy-cat glass solar filters, call us.

SOLAR ECLIPSE VIEWERS

Mylar: Aluminized on both sides. Mounted in rigid frame. Mylar window: 1-5/8" x 3-1/8". Each filter supplied in individual envelope. Light transmission is blue.

3" x 5" Overall size .... **$1.00 ea.**

Plastic: Same as Mylar except this filter yields a sharper image with orange transmission

2-5/8" x 4-5/8" Overall size .... **$2.00 ea.**

Minimum order of 10 eclipse filters in any combination. Please add appropriate shipping/handling. *10 units: $3.00. Plus $1.00* for each additional 10 units. Minimum credit card order of $25.00. Quantity discounts available starting at 100.

Mylar and plastic viewers are coated to a neutral density of 5. Transmission in visual light is approximately 1/1,000th of one percent. There is no significant transmission in ultraviolet or infrared. Designed for naked eye visual use.

Free brochure available.

Foreign inquiries: Please include $1 for return airmail postage of brochure. Proforma invoices available upon request.

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Solar filters are shipped free in continental U.S. when payment is included with order. Shipping extra on credit card orders ($3-$6 depending on aperture). Payment may be made by personal check, bank check or money order. We also accept **Visa, MasterCard** and **American Express. PLEASE SPECIFY TELESCOPE BRAND AND/OR OUTSIDE DIAMETER MEASUREMENT OF TELESCOPE TUBE.** The cost of the filter is based on the telescope aperture. The mounting cell fits over and around the end of the telescope tube (friction fit). The coating faces the inside. Unmounted filters are the glass only.

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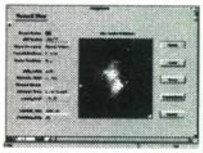

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ASTRONOMY BOOKS

Solar System in Chaos

Newton's Clock: Chaos in the Solar System

Ivars Peterson, (W. H. Freeman and Co., 1993), ISBN 0-7167-2396-4, 317 pages, hardcover, $22.95.

In dynamics, chaos means that if you start a body in motion in a slightly different way than an identical body, the motions of the two bodies at a later time will be significantly different. To put it another way, if you know the position of an asteroid now, you can't know its position several billion years ago. While the laws of Kepler and Newton describe the orbits of the major planets with clockwork precision, chaos prevails in the dynamics of asteroids, satellites such as Saturn's Hyperion, and planetary rings.

Peterson describes how astronomers confronted chaos in the Moon's orbit and found that this complex motion applied elsewhere in the solar system. He also discusses the new computers, such as the Digital Orrery and the Supercomputer Toolkit, that enable researchers to study chaotic orbits and trace the history of the solar system.

Exploring Planetary Worlds

David Morrison, (Scientific American Library, 1993), ISBN 0-7167-5043-0, 238 pages, hardcover, $24.95.

Most books about the solar system describe each planet in turn, usually starting closest to the Sun with Mercury and ending with distant Pluto. Morrison groups the planets together and compares and contrasts these bodies to draw out the larger lessons the planets have to tell us about the solar system in general and Earth specifically. His comparative analysis starts with the giant planets, Jupiter, Saturn, Uranus, and Neptune, using information obtained by the Voyager spacecraft. (Morrison was a member of the Voyager imaging team.) He then discusses the cratered worlds of the Moon and Mercury, the twin planets of Venus and Earth, and the planet most like Earth, Mars. Two of the six chapters reveal the nature of the solar system's smaller bodies: satellites, asteroids, and comets. Because these bodies are remnants from when our planetary system formed, Morrison uses them to discuss the origin of the planets.

What if the Moon Didn't Exist?

Neil F. Comins, (HarperCollins, 1993), ISBN 0-06-016864-1, 304 pages, hardcover, $20.

Readers of ASTRONOMY are familiar with Neil Comins and his "What if" writings. This collection of 10 essays continues these writings and describes life on an Earth-like planet that orbits a more massive star, tilts like Uranus, has more mass, has its ozone layer depleted, doesn't have a Moon, has a closer Moon, lies near a supernova explosion, has another star pass nearby, or has a black hole pass through it. Four of the essays expand upon the themes of the articles in ASTRONOMY ("The Earth Without the Moon," February 1991; "Seeing the World through Infrared Eyes," June 1991; "Life around a Larger Sun," May 1992; "A New Slant on Earth," July 1992). The rest are new and provide the same thought-provoking questions that help us realize what a special place Earth is.

Edwin Hubble, the Discoverer of the Big Bang Universe

Alexander S. Sharov and Igor D. Novikov, (Cambridge University Press, 1993), ISBN 0-521-41617-5, 224 pages, hardcover, $34.95.

Originally published in Russian, this biography covers the life of Edwin Hubble from his birth in Missouri in 1889 to his death in 1953. The bulk of the volume discusses Hubble's astronomical career and discoveries, the most famous of which is the expansion of the universe. However, Sharov and Novikov maintain a personal touch about Hubble's life and work even in these sections. A final chapter describes the work carried on in observational cosmology by other astronomers since Hubble's death.

The "Non-Existent" Star Clusters of the RNGC

Brent A. Archinal, (The Webb Society, 1993; in North America contact Ron Morales, 1440 South Marmora Avenue, Tucson, AZ 87513-1015; outside North America contact Don Miles, 96 Marmion Road, Southsea, Hampshire PO5 2BB, England), 110 pages, softcover, $9.50 (in North America); £4.95 (outside North America).

Since the origin of the *New General Catalogue* and its revision (RNGC) by Sulentic and Tifft, a number of objects have become "lost." The original observers misidentified these objects, viewed some objects twice (and thus created duplicate entries), or simply jotted down the wrong position, causing

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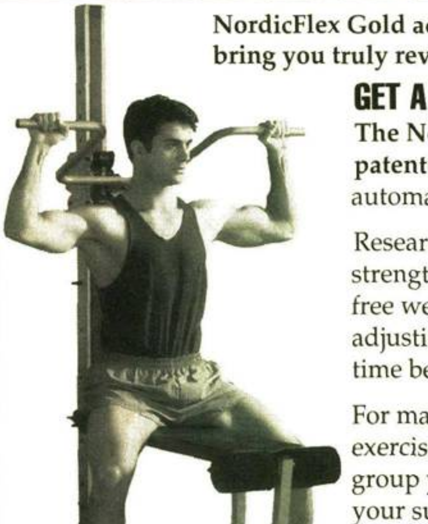

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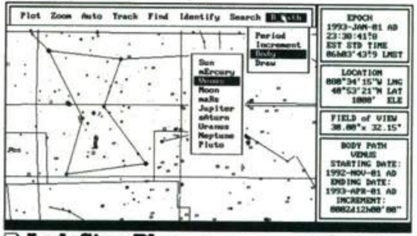

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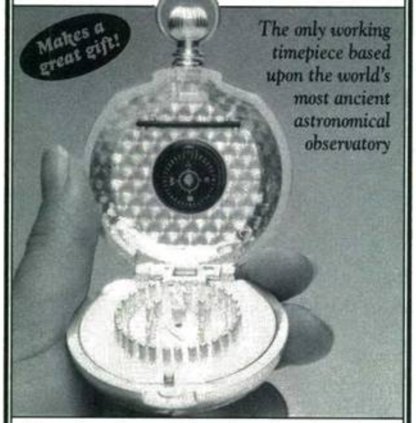
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later astronomers to miss the cluster. Archinal investigates 229 of these missing star clusters. He concludes one probably doesn't exist, 5 are duplicate entries of other NGC objects, and 99 are observable groups or clusters of stars.

Over 100 clusters remain missing. Archinal provides notes about all except 21 of the missing objects and drawings of 32 clusters. A table lists right ascension, declination, magnitude, and *Uranometria 2000.0* chart number for each cluster to help you find these objects with your telescope. The Webb Society encourages you to make and report observations of these missing star clusters.

The Sky at Night, 10

Patrick Moore, (John Wiley and Sons, 1992), ISBN 0-471-93763-0, 182 pages, softcover, $19.95.

These excerpts from Moore's television program, *The Sky at Night,* come from its 31st through 36th seasons (1988-1992). Some discuss the night sky, such as the chapters on Taurus the Bull and Polaris the Pole Star. Others take you to the Baikonur launch complex in Kazakhstan, the Keck telescope on Mauna Kea in Hawaii, and the Armagh Observatory in Northern Ireland. Moore also describes some astronomical satellites such as the International Ultraviolet Explorer, ROSAT, Magellan (the Venus probe), Hubble Space Telescope, and Galileo (the probe on its way to Jupiter).

McGraw-Hill Encyclopedia of Astronomy

Sybil P. Parker and Jay M. Pasachoff, editors, (McGraw-Hill, Inc., 1993), ISBN 0-07-045314-4, 531 pages, hardcover, $75.50.

Hundreds of entries, written by many distinguished astronomers, explain important concepts of astronomy. The descriptions at times are somewhat technical and occasionally involve mathematics, making this book more appropriate for advanced rather than beginning amateur astronomers. Lots of black-and-white photos (with 16 four-color plates scattered throughout the volume) and two-color illustrations help to demonstrate the concepts.

Annual Review of Astronomy and Astrophysics

Geoffrey Burbidge, David Layzer, and Allan Sandage, editors, (Annual Reviews Inc., 1993), ISBN 0-8243-0930-8, 787 pages, *acid-free paper, hardcover, $57.*

Leading experts review the state of knowledge in different fields of astronomy. Planetary scientists describe the atmospheres of Uranus and Neptune, Jupiter's Great Red Spot, and the evolution of orbits in the solar system. Stellar astronomers discuss supernova 1987A, the faintest stars, and the origin of X-ray binaries and binary pulsars. Galaxy experts report on the distance to the center of our Galaxy, models of active galaxies and quasars, the spectra of active galaxies, and the nature of high-redshift radio galaxies. Other articles outline the new techniques of adaptive optics and tests of cold dark matter cosmologies.

Discover Planetwatch

Clint Hatchett, (Hyperion, 1993), ISBN 1-56282-874-6, 128 pages, softcover, $9.95.

Seventeen projects introduce you and your children to the motions of the Moon and planets and to observing the planets through a small telescope. The projects include following the phases of the Moon, measuring lunar craters and mountains (requires a calculator), building a scale model of the solar system, and watching Jupiter's four largest satellites. One project requires a computer planetarium program to study Pluto's orbit. Simple seasonal star maps plot the major constellations.

The Eye of Heaven

Owen Gingerich, (American Institute of Physics, 1993), ISBN 0-88318-863-5, 442 pages, hardcover, $24.95.

What triggered the Copernican revolution? Gingerich explores in this collection of 25 essays, reprinted from journals usually not available to amateur astronomers, the transformation of astronomy from a geocentric to a heliocentric view of our solar system. Some of the essays explore whether Ptolemy faked his data, Copernicus owed his theory to the Greek astronomer Aristarchus, and early astronomers believed that the heliocentric theory was just a model or represented reality. Others discuss why so few astronomers in the 16th century saw the aesthetic unity that Copernicus' theory provided and how science would have changed if Newton had not lived.

Principles of Physical Cosmology

P. J. E. Peebles, (Princeton University Press, 1993), ISBN 0-691-01933-9, 718 pages, acid-free paper, softcover, $29.95.

Peebles, a leading cosmologist, provides a comprehensive description of the expansion of the universe, dark matter, the origin of galaxies, the cosmic background radiation, alternative cosmologies, and the geometry and large-scale structure of the universe. The text requires an understanding of undergraduate physics and advanced calculus. ☐

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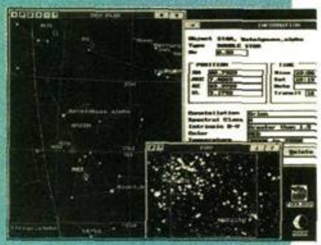

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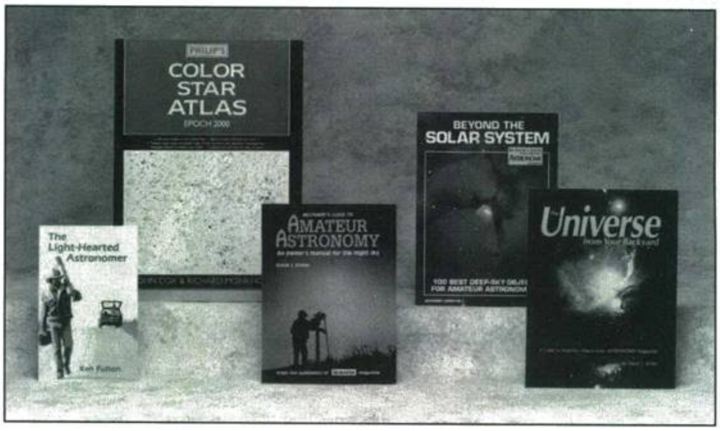
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Galaxies by Timothy Ferris (The Sierra Club, 1980). A tour through the universe of galaxies including information on the Local Group, the Milky Way, and the Magellanic Clouds.

The Moon-Miner's Daughter (page 34)

The Geologic History of the Moon by Don E. Wilhelms, (U.S. Geological Survey Professional Paper 1348, 1987). Best survey of lunar geological history; profusely illustrated; assumes familiarity with geology terms and concepts but is quite readable nonetheless.

Lunar Sourcebook by Grant Heiken, David Vaniman, and Bevan French (Cambridge University Press, 1991). A detailed summary of lunar knowledge for the professional scientist; also contains summary chapters fairly accessible to lay readers.

Cosmic Chameleon: The Supernova in M81 (page 40)

"Insight into Star Death" by Richard Talcott, ASTRONOMY, February 1988. Describes the explosion of supernova 1987A and the nature of its progenitor star.

The Supernova Story by Laurence Marschall, (Princeton University Press, 1994). A general account of how supernovae occur.

Glorious Visions (page 68)

Light and Color in the Outdoors by M. G. J. Minnaert (Springer-Verlag, 1993). Sharp eyes on a dark night show many colors and lights in the night sky — this guide describes them in detail.

Sunsets, Twilights, and Evening Skies by Aden and Marjorie Meinel (Cambridge, 1983). An overview of sky lights with an emphasis on sunset phenomena and twilight science.

Sunblock (page74)

Annular Solar Eclipse of 10 May 1994 by Fred Espenak and Jay Anderson (NASA Reference Publication 1301, Washington, 1993). A detailed preview of the circumstances for the May eclipse.

Eclipse by Bryan Brewer (Earth View, 1978). A general introduction to eclipses and how to view them.

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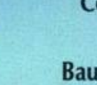

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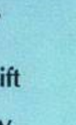

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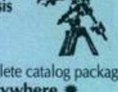

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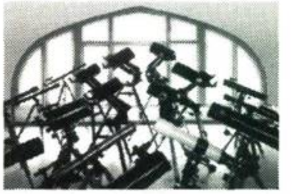

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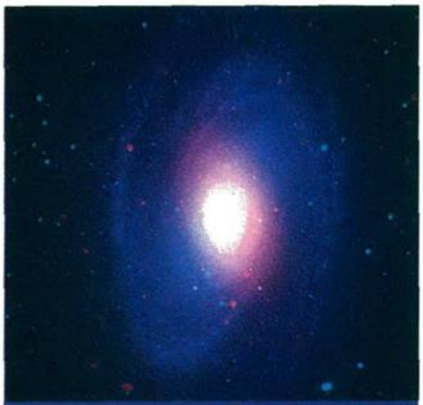

Tony and Daphne Hallas

COMING IN THE
MARCH 1994
ISSUE OF
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SEVEN MYSTERIES OF GALAXIES How do galaxies form? Why do they come in so many shapes? What does the future hold for the Milky Way? Astronomers are seeking answers to these questions about the basic building blocks of the universe.

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EXPERIENCE

ASTRONOMY MAGAZINE REVIEWS GENESIS-SDF

Excerpts from Alan Dyer's review in the January '94 issue:

"The newest version of Tele Vue's Genesis refractor offers first-class optics in a convenient and highly portable package...

...On critical star tests, the Genesis-sdf performed flawlessly. Both pairs of the double-double star Epsilon Lyrae appeared cleanly split with dark sky between the tiny, sharply defined stars. Saturn was sharp and contrasty, with the Cassini division in the rings as well as color differences in the belts and zones on the planet's disk clearly visible.

The level of color correction in the SDF was impressive. The edge of the Moon was pure white. Saturn appeared without any trace of a blue halo. The zero magnitude star Vega, one of the toughest tests, showed the merest hint of a blue halo that came and went with seeing conditions. This is a superb level of color correction in any refractor, let alone one this fast and portable.

The flat field was apparent when scanning star field with Tele Vue's 35mm Panoptic eyepiece, itself optimized to provide a wide, flat field.

Combined with premium wide-angle eyepieces, this is a telescope capable of providing stunning low-power views of Milky Way starfields. And yet under good seeing conditions, the sharp optics will easily handle 200 to 250 power for crisp lunar and planetary views.

Genesis serves as a superb deep-sky astrophoto scope. Test shots on 35mm film of starfields in Cygnus exhibited sharp star images corner to corner across a 4° field.

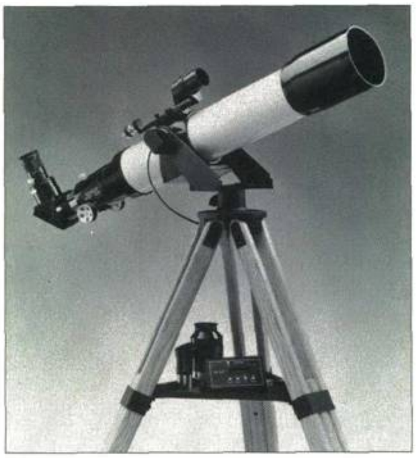
The rack-and-pinion focuser operated smoothly with no backlash or image shift. The focuser accommodates 2-inch accessories and has a screw for tightening the tension. The focuser did not slip even with heavy cameras or eyepieces attached.

I tested the Genesis on Tele Vue's alt-azimuth mount, the Gibraltar, a well-crafted mount made of machined and black-anodized aluminum. The wood tripod is made of ash. The mount has smooth Dobsonian-like motions, making it easy to nudge this scope every few moments to recenter the image.

Tele Vue offers a finder called the Starbeam. When you look through this nifty device, you see a red dot projected against the naked-eye sky. The dot shows you exactly where the scope is pointed.

I also checked out Tele Vue's new Air-Chair seat, a sturdy, well-padded stool with a handy pneumatic height adjustment. Whether you are looking at the horizon or at the zenith, you can remain comfortably seated without the need to stretch or crouch, a convenience that adds immeasurably to the pleasure of using this telescope.

In all, I found the package well engineered and friendly to use. If a portable, high-performance, and beautifully finished instrument is what you are seeking in an astronomical telescope, the Genesis-sdf is an excellent choice."



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Pronto

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No picture or description prepared me for the beauty of the design or the excellence of the workmanship. J.T. - RI

The detail it shows on Jupiter is absolutely unbelievable. B.D. - CO

I was able to see Jovian lunar shadow transit easily with this instrument. I love the design and features - I may have to buy a Genesis! R.G. - PA

It's almost as if I'm not using a scope at all. Too many scopes just get in the way and make observing a frustrating experience. T.Z. - NY

Wanted a first telescope with superior optics, portability and value. I got what I asked for, wonderful little thing. J.P. - U.K.

Well done! Saw the Owl and M108 in same field. T.J. - KS

The Genesis-sdf, 20mm Nagler Type 2, and Gibraltar mount combination is a game breaking touchdown! G.B. - NJ

Compact, easy to carry & solid case. Delivers one of the best, false-colour-free images I've ever seen in this size & aperture! Thank you. B.D. - Germany

WOW! Easily split Nu Scorpii and Antares! Jupiter looks great ! D.S. OH

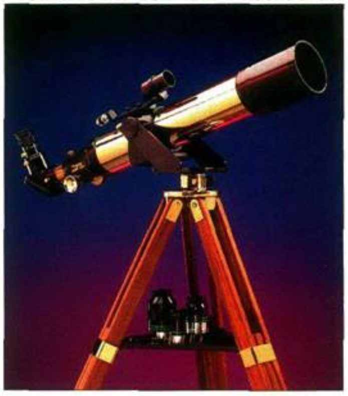
I am greatly satisfied with the quality of craftsmanship that was put into this fine instrument. M.H. - PA

Fantastic! Sharp views of planets, moon and star fields...excellent high power results!! J.C. NJ

It's the only scope I recommend to friends. B.H. - KS

Superb optics! Sharpest images of any scope I've ever owned. Pinpoint star images. R.M. MD

Renaissance-SDF: Solid Brass



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Take Home The Orion Nebula

The constellation Orion dominates the winter sky, its bright stars are easily recognized from the light polluted skies of urban areas. Nestled just below the three stars that make up the belt of Orion lies M42, the famed Orion Nebula. Discovered by Nicholas Peiresc in 1610, early observers called this the most remarkable object in the heavens. And for good reason. Viewed at low power, this huge stellar nursery fills the field seen through the telescope. Wisps of gas and dust fold back on the central stars seemingly protecting its stellar infants. Today, it is still a classic object that amateur sky gazers turn their telescopes to again and again.

Take home the Orion Nebula for yourself with the Celestron Ultima 8 telescope. Designed for the discriminating celestial photographer, the Ultima 8 uses a precision worm gear drive and Periodic Error Correction (PEC) for the ultimate in tracking accuracy. The massive polar shaft produces unparalleled stability. The unit comes standard with Starbright® coatings on the primary and secondary mirrors for the brightest images possible. And, the corrector plate is now made of optical crown glass! All this combines to produce the ultimate visual and photographic telescope — the Ultima 8! And, dozens of accessories expand the usefulness of this telescope for all forms of celestial photography.

Take home the Orion Nebula & other wonders of the universe with the Celestron Ultima 8.

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